

FUNCTIONAL BRAIN SYSTEMS AND PERSONALITY DYNAMICS

By

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TABLE OF CONTENTS

ACKNOWLEDGEMENTS.....	iii
LIST OF FIGURES.....	vii
ABSTRACT.....	viii
CHAPTER	
I INTRODUCTION.....	1
II THE PHYSIOLOGICAL SUBSTRATE OF PERSONALITY: A SELECTIVE REVIEW OF THE LITERATURE.....	7
Review of Basic Brain Anatomy and Organization.....	8
Cortical Mechanisms.....	8
Subcortical Systems.....	12
The Interpretation of Neurology Literature.....	17
Human Consciousness.....	18
Right versus Left.....	18
Language and the Left Hemisphere.....	20
Aphasia: Anatomy and Syndromes.....	21
Language, Symbolism, and Meaning.....	24
Human Consciousness, Self-Awareness, and Thought.....	26
Discussion.....	35
Cortical Mobilization: Attention, Arousal, and Activation.....	39
The Reticular Activating System and Tonic Arousal.....	39
Phasic Control Systems: The Frontal Lobes and Thalamus.....	41
Discussion.....	44
Motivation: Emotion and Affect.....	45
Amygdala Circuits and the Prefrontal Lobes.....	46
Affective Expression.....	48
Discussion.....	50
Memory Functions.....	51
Human Amnesia Syndromes.....	57
Memory and the Neocortex.....	63
Discussion.....	68
The Limbic System, RAS, and Memory.....	70
Papez Circuit and Memory.....	74
Fornix.....	75

	Mammillary bodies and mamillothalamic tract..80
	Cingulate cortex.....81
	Discussion.....83
	Interfaces and Interactions of the Monitoring, Motivating, and Mobilization Systems.....89
	The Biochemistry of Emotion, Motivation, and Learning.....92
	Emotion, Amygdala Circuits and Memory.....95
	Discussion.....103
	Biochemical and Electrophysiological Aspects of Cortical Mobilization Processes.....104
	The Functional Elements of the Personality Structure.....108
	The Problem-Solving/Response-Generating System.....109
	The Memory System.....110
	The Motivating System.....112
	The Mobilization System.....114
	Learning and Memory: Animal Studies.....115
	A Functional Meta-system.....120
	Lateralized Mobilization Processes.....125
	Asymmetrical reaction time to laterally presented stimuli.....125
	Altered GSR following unilateral brain injury.....126
	Asymmetrical biochemical and electro- physiological processes.....127
	Bilateral Interaction in Emotion and Cognition..128
	Mental Health and Psychopathology.....136
	The Psychopathological Correlates of Unilateral Temporal Lobe Epilepsy.....139
	Discussion: Hyper- and Hypo-dominance Spectrum Disorders.....141
	Schizophrenia and the Affective Disorders.....143
	Anxiety Disorders, Obsessive-Compulsive Illness, and Paranoia.....145
	Sociopathy and Hysteria.....147
III	METHOD.....151
	Subjects.....152
	Instruments.....153
	Procedure.....154
	Hypotheses.....155
IV	RESULTS.....156
	Left versus Right Hemisphere Cognitive Functioning Between Groups.....156
	Overall Performance on the Tests Sensitive to Right versus Left Hemisphere Cognitive Functioning.....157

	Differences in MMPI Scores.....	157
	Age.....	159
V	DISCUSSION.....	160
APPENDICES		
A	HYPO- AND HYPER-DOMINANCE SPECTRUM DISORDERS BY DSM III DIAGNOSTIC CLASSIFICATION.....	165
B	INFORMED CONSENT STATEMENT.....	166
C	REVISED SCORING CRITERIA FOR THE STREET (1931) GESTALT COMPLETION TEST.....	167
	BIBLIOGRAPHY.....	168
	BIOGRAPHICAL SKETCH.....	188

LIST OF FIGURES

FIGURES

- 1 Cytoarchitectural map of the lateral and medial
surfaces of the human cerebral cortex, with numbers
representing the areas of Brodman.....10
- 2 Partially schematized representation of the
limbic system.....13
- 3 The position of Papez's circuit within a
larger cortical circuit.....86
- 4 Schematic representation of the proposed model of
the physiological substrate of personality.....111

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A heuristic model of the physiological substrate of personality structure was developed from a review of recent neurological and physiological psychology literature. The formulation of the model was based on assumptions that the phylogenetic transition from instinctive responding to self-determined behavior required the evolution of automatic neural mechanisms to insure that the organism would monitor the environment for significant stimuli, be motivated to respond in the presence of those stimuli, and mobilize the appropriate psychological operations to determine the form of that response. Functional elements of these basic mechanisms were identified and a functional meta-system was outlined which would organize the elements and optimize the utilization of lateralized cognitive processes in the interest of assuring the emission of adaptive behavior.

The proposed model suggests that certain psychodiagnostic entities might be classified as hyper- and hypo-dominance spectrum disorders

based on the form of dysfunction within the meta-system. The ability of the model to predict membership in diagnostic categories was tested by assigning 42 adult psychiatric inpatient and outpatient subjects to hyper-dominant and hypo-dominant groups by diagnosis, according to the constructs of the model, and comparing performance on instruments shown to be sensitive to right and left cerebral hemisphere dysfunction. The Street Gestalt Completion Test and the Object Assembly, Similarities, and Information Subtests of the Wechsler Adult Intelligence Scale-Revised were administered to each subject. An abbreviated form of the Minnesota Multiphasic Personality Inventory (MMPI) was used to compare symptomology between groups.

Significant between-group differences ($p < 0.001$) in the ratios of test scores sensitive to right versus left cognitive functioning were found in the predicted directions, while the groups did not differ in overall performance on the instruments. Significant differences ($p < 0.005$) in the ratios of selected MMPI clinical scales, in the predicted direction, provided further support for the hypothesized relationship between lateralized cognitive functioning, symptomology, and diagnosis.

It was concluded that the proposed model provides tenable and potentially useful operational definitions of personality functions and psychopathology. Results were discussed in terms of their implications for psychotherapeutic interventions and additional methods to test the validity of the model.

CHAPTER I INTRODUCTION

The various schools of psychotherapy agree that the practitioner's task is to facilitate change in the client. They agree on little else. There is, as yet, no consensus regarding the two major issues in psychotherapy: what is to be changed, and how that change is to be brought about (Strupp, 1978). Strong opinions about both of these basic problems are available; data based conclusions are not. Proponents of fundamentally different viewpoints debate acrimoniously (Eysenck, 1974); yet verifiable differences in outcome between theory-based forms of intervention are rare (Bergin & Lambert, 1978). This unsatisfactory state of affairs in applied psychology has unfortunate consequences for practitioners and their clients alike.

The problem has been ascribed by Watson to the "preparadigmatic" state of the discipline of psychology. According to Watson "psychology has not experienced anything comparable to what atomic theory has done for biology, what laws of motion have done for physics. Either psychology's first paradigm has not been discovered yet or it has not been recognized for what it is" (Watson, 1967, p. 53). Hanson stated the problem succinctly: "The issue is not theory using, but theory finding" (1965, p. 3).

The two major forces in psychological thought, psychoanalysis and behaviorism, have encountered significant problems. Theories

based on the former have been criticized as untestable and therefore unscientific (Eysenck, 1970). The latter movement lost impetus with the discovery by Olds and Milner (1954) of "pleasure" centers in the brain. This revelation undermined the basic assumption of the learning theorists that behavior could be explained simply by defining the rules governing stimulus-response relationships.

Successful scientific theories are built on paradigms that describe the fundamental properties and mechanics of their subject. The fundamental units of personality are networks of neurons in the brain. Sigmund Freud (1948) attempted to relate mental structures to anatomical locations but was forced to abandon his effort because the neurology of the time was not adequate. Instead he and subsequent theorists were forced to base their models on suppositions about the products of the personality processes. As noted above, the results have been less than satisfactory. The science of neurology has made significant progress in the interim and a large amount of useful information has accumulated. These data have been virtually ignored by the discipline of psychology. The intergration of neurological data and psychological theory may provide a basis for a useful paradigm for the psychotherapist. The present work is intended as a step toward such an integration.

The purpose of this study is to develop and test a heuristic model of personality function, based on an understanding of its physiological substrate, with the ultimate goal of improving the effectiveness of psychotherapeutic interventions. Such a model should identify the basic elements and processes of the personality

structure and describe the ways in which these interact to produce psychological health and psychopathology. Such a model might lead to new operational definitions of psychological phenomena which, in turn, may suggest new intervention points and methods.

The purpose of a theory is to integrate known facts within a single framework and account for them in terms of a small number of interrelated concepts. Existing theories suffer from a lack of integration. The discipline of psychology has hindered such integration by institutionalizing a tradition of subspecialization: theories of attention, perception, cognition, motivation, emotion, behavior, etc. are developed in relative isolation. The failure of individual theorists to understand and to appreciate the interrelatedness of these various personality operations may account for the inadequacy of psychological theory in general. It is assumed here that the component parts of the personality can only be properly understood in the context of their relationship to the whole; that more will be gained from a gross (but comprehensive and testable) description of the personality infrastructure than from a detailed examination of a single personality operation.

Rather than subdivide the personality structure on the basis of notions of what it should do; it might be more productive to approach the problem on the more basic level of what it must do. The formulation of the model will be guided by a set of assumptions about the evolutionary pressures which shaped the personality structure. These "evolutionary imperatives" are as follows:

1. The physiological substrate of personality evolved to assure the emission of adaptive behavior by the organism. Survival pressures shaped an organization that was able to respond effectively to significant stimuli and produce behavior that enhanced the organism's well-being.

2. The evolution of this substrate proceeded from an organization based on "hard-wired" stimulus-response instincts to an organization which allowed increased latitude in behavior in order to take advantage of the organism's developing problem-solving abilities.

3. In order to permit self-determination of behavior and, at the same time, to insure survival, new mechanisms were required to assure that the organism would (a) attend to significant stimuli; (b) be motivated to respond effectively to those stimuli; (c) accomplish the mobilization of the necessary psychological resources to determine the form of that response (referred to hereafter as the Monitoring, Motivating, and Mobilization systems).

4. Although these systems interact, they must be functionally separated to the extent that they do not interfere with each other's normal operation. Similar functions might be carried out in other brain areas, but the automatic activation of these systems will assure that they dominate responding to stimuli which relate to the survival and well-being of the organism.

5. As these mechanisms are essential for the survival of the individual and species they will form the central organizing processes of personality; personality dynamics will center on their operation.

Neurological theories of mental function center on clinical observations of patients with localized brain lesions. The history of neurological thought has revolved around the question of how these data are to be interpreted. For many years higher mental functions were treated as discrete "faculties." The results were inconsistent and of little value. The failures of these "narrow localizers" led to theories which attempted to account for mental functions on the basis of the "mass action" of the brain. Where earlier models were too specific, these theories proved too general to be useful.

In the 1920s Goldstein broke with the tradition of attempting to infer functions directly from deficits and proposed instead an "analysis of basic disturbances." This approach led finally to Luria's conceptualization of mental activities as the product of the interaction of complex functional systems. In Luria's formulation a mental function is the result of contributions from a number of concertedly working zones. Therefore, that function may be destroyed, or disturbed differently, by lesions in different locations. Luria (1973a) described the characteristics of a functional system:

The presence of a constant (invariant) task, performed by variable (variable) mechanisms, bringing the process to a constant (invariant) result, is one of the basic features distinguishing the work of every "functional system." The second distinguishing feature is the complex composition of the "functional system," which always includes a series of afferent (adjusting) and efferent (effector) impulses. (Luria, 1973a, p. 28)

Luria outlined three principal functional units in the brain: the "units for regulating tone and waking and mental states," centered on the reticular activating system in the brainstem; the

"unit for receiving, analyzing and storing information," operating in the post-central (sensory) areas of the brain; and the "unit for programming, regulation and verification of activity," operating in the frontal lobes (Luria, 1973a, ch. 2).

Luria's concepts represent a major advance in the understanding of the fundamental operating characteristics of brain systems. Although his formulations are too basic to be of much use to the applied psychologist, he has established a format and a methodology which will be followed here. The present investigation will focus on identifying and describing the interactions of the functional brain systems which satisfy the requirements of the evolutionary imperatives outlined above. Evidence suggests that the substrate for these systems will be found in those anatomical areas for which Luria acknowledged he had inadequate data for his own analyses: the medio-basal zones of the cortex and the right hemisphere of the brain.

CHAPTER II
THE PHYSIOLOGICAL SUBSTRATE OF PERSONALITY:
A SELECTIVE REVIEW OF THE LITERATURE

In the following sections the neurological and physiological psychology literature pertaining to the functional/anatomical organization of personality will be reviewed. The data will be related to psychological factors and any conclusions will be noted in discussions at the end of each section. The first section is a review of basic brain anatomy and organization. The second section will examine the physiological substrata of consciousness and conclude that human consciousness, characterized by self-awareness, is a manifestation of processes which occur in the left hemisphere of the brain. The third section will trace the systems involved in cortical activation and note the existence of two mechanisms within each hemisphere which have opposite effects on the form of cognitive processes. The fourth section will examine the role of the amygdala and frontal lobes in the subjective experience of emotion and of the right hemisphere in the expression of affect. The fifth section will develop the basis for a theory of memory function and the role of memory systems in organizing affective, arousal, and cognitive processes. The sixth section will focus on the interactions of the emotion, arousal, and memory systems and examine the role of bio-chemically mediated systems in coordinating these processes. In the seventh section a model of four functional systems which

constitute the basic elements of the personality structure will be proposed. The eighth section will describe the way in which the basic elements are organized into a functional meta-system which forms the infrastructure of personality and functions to assure the emission of adaptive behavior. This model will be supported with evidence concerning the psychological correlates of neurological syndromes. In the final section the psychological phenomena associated with various forms of psychopathology will be related to neurological indices which reflect the operation of the lateralized subsystems and their interaction within the functional meta-system. It will be concluded that many psychodiagnostic entities may be classified as hypo- or hyper-dominance spectrum disorders which are functionally related to chronic, and maladaptive, under- or over-utilization of the mechanisms in the left hemisphere of the brain.

Review of Basic Brain Anatomy and Organization

Cortical Mechanisms

Although certain phylogenetically new areas of the cerebral cortex are of special interest when discussing "higher mental functions," these areas must be considered in their physiological and evolutionary context. A brief review of basic brain systems and anatomy will establish this perspective.

In man, as in all mammals, large portions of the cerebral cortex are devoted to the more elementary functions of processing sensory stimuli and the initiation and control of movements. The brain structures subserving these basic functions are divided at the

central fissure (Rolando). Incoming somato-sensory, visual and auditory nerve impulses are relayed, via the thalamus, from contralateral receptor surfaces to primary projection areas located in the parietal, occipital and temporal lobes (see Fig. 1, areas 1, 2, 3; 41; 17), respectively (Noback & Demerest, 1972). In each case the modally specific, somatotopic organization of nerve impulses in the projection areas is transformed into functional information (i.e., acquires meaning) in an adjacent secondary association area (areas 5, 7, 18, 19; 42). With each new level of processing there is increasingly complex synthesis of information and decreased modal specificity (Luria, 1973a). Damage to a primary projection area results in a loss of sensation (e.g., blindness) while lesions of a secondary association area are likely to produce the inability to recognize a stimulus in that modality (agnosia). Conversely, artificial stimulation of a projection area produces a discrete sensory experience while stimulation of a secondary association area elicits a more elaborate sensory hallucination whose complexity is related to the level within the hierarchy that is activated (see Mullan & Penfield, 1959).

Progression within the hierarchy is reversed in the motor systems. Specificity of control increases as the secondary (pre-motor) areas (areas 6 and 8) coordinate and fine tune their influence on the pyramidal cells of the primary motor cortex (area 4) with the assistance of continuous feedback from the sensory modalities. Lesions of the primary motor cortex produce contralateral paresis while stimulation elicits flexion of individual muscle groups.

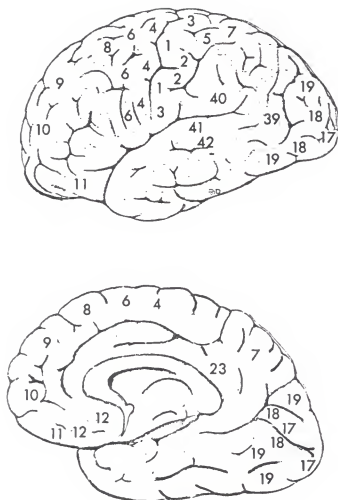


Figure 1. Cytoarchitectural map of the lateral and medial surfaces of the human cerebral cortex, with numbers representing the areas of Brodman. (Redrawn from Noback & Demerest, 1972).

Stimulation of secondary motor areas produces smooth, coordinated movements and ablation of these areas may result in the loss of ability to perform skilled motor acts (apraxia) (Noback & Demerest, 1972).

The systems described thus far are typical of all mammals and become progressively more elaborate and efficient in the higher primates. Evolution proceeds generally by modifying and elaborating existing hardware, allocating new functions to tissues which are in some way pre-adapted to assume the new tasks (Campbell, 1974). The development of higher mental functions in man is correlated with bilateral anatomical expansion of two cortical areas which are adjacent to the secondary association areas described above. These regions subserve the highest level of organization in the hierarchies and are called tertiary association areas (Luria, 1973a). Both areas are involved in what Penfield (1975) referred to as "trans-actions of the mind."

The inferior parietal lobule (IPL) (areas 23; 39, 40) lies at the anatomical confluence of the secondary association areas in the post-central cortex. This area is the "association cortex of association cortices" (Geshwind, 1979). Here processed information from the surrounding sensory association areas is further integrated and synthesized. The area is called "supramodal" because its individual units can only be excited by the simultaneous stimulation of two or more sensory modes (Luria, 1973a). Information processing at this level is "abstract" in that it is independent of a particular sensory modality (cf. Osgood, 1953). This ability allows the

simultaneous synthesis of information which permits the mental manipulation of the relationship between information units and as such is a prerequisite for the high level mental functions that are characteristic of human beings (Luria, 1973a).

At the anterior pole of the brain, contiguous with the secondary motor association areas, the prefrontal lobes (areas 9-12) are dramatically enlarged and now represent up to one-fourth of the entire cortical mass. The prefrontal lobes have extensive two-way connections with all other parts of the cerebral cortex (Luria, 1973a). The coordinating and control operations carried out by the lower level (motor) systems in this hierarchy are evident in the functions of the tertiary integration areas. The frontal lobes have been called the "executive of the brain" (Pribram, 1973). They are the seat of Luria's "unit for programming, regulation and verification of activity" (Luria, 1973a). Lesions of the frontal lobes lead to a defect in the patient's "capacity for planned initiative" (Penfield & Evans, 1940), and to disturbances on impulse control (Pribram, 1973).

Subcortical Systems

The limbic system consists of a group of interconnected structures, situated between the midbrain and the neocortical mantle, including the hypothalamus, amygdala, hippocampus, septal area, and cingulate cortex (see Fig. 2). Because of their relationship to the olfactory bulbs, these structures were originally thought to be concerned with that function and so this area of the brain was designated the rhinecephalon ("nose-brain"). Although

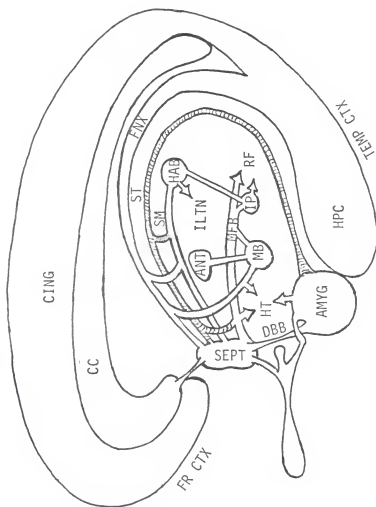


Figure 2. Partially schematized representation of the limbic system. FR CTX - frontal cortex; CING - cingulate cortex; TEMP CTX - temporal cortex; CC - corpus callosum; SEPT - septal area; AMYG - amygdala; HPC - hippocampus; HT - hypothalamus; MB - mammillary bodies; ANT - anterior thalamic nuclei; HAB - habenula; ILTN - intralaminar thalamic nuclei; IP - interpenduncular nucleus; RF - reticular nucleus; DBB - diagonal band of Broca; MFB - median forebrain bundle; SM - stria medularis; ST - stria terminalis; FNX - fornix. (Redrawn from Isaacson et al, 1973)

lower animals depend on the sense of smell for such survival-related activities as food-getting, the detection of enemies, and mating (MacLean, 1949), the role of these subcortical structures in motivational and emotional processes was not appreciated until the 1930s. Since Kluver and Bucy (1938) published their description of altered emotional behavior following the bilateral removal of the temporal lobes, including the amygdalae and hippocampi, limbic system components have been the subject of intense scrutiny. The massive literature which has accumulated is filled with confusing inconsistencies and conflicting findings. This may be due in part to the fact that the function of these structures appears to vary according to environmental circumstances (Olds, 1958). Although a number of tentative models of limbic system function have been offered (e.g., Papez, 1937; Gloor, 1956; Olds, 1958) none has found general acceptance.

MacLean (1970) distinguishes three major types of systems in the mammalian brain which correspond to stages in its evolutionary development. He describes a protoreptilian core-brain, a paleomammalian brain (the limbic system) and a neomammalian brain (the neocortical areas). This triune brain conceptualization provides a useful perspective on the hierarchical arrangement of anatomical and functional systems and their relationship to behavior (Isaacson, 1974).

The protoreptilian brain represents the fundamental core of the nervous system consisting of areas homologous to parts of the upper brainstem and midbrain, hypothalamus, and basal ganglia.

In primitive organisms this brain produces a repertoire of instinctive, stereotyped behaviors which are sufficient to insure the survival of the individual and species. These unlearned, species-specific behavior patterns relate to the elementary functions of obtaining food and shelter, establishing and defending a home territory, breeding, maternal behavior, etc. (Isaacson, 1974). Programs for these behavior patterns are apparently stored in the brainstem and triggered by the hypothalamus: complex behavior sequences such as eating, drinking, sexual acts, aggression and many other types of unlearned behavior can be elicited by electrical stimulation of the hypothalamus at levels below those needed to activate motivational systems (Isaacson, 1974). In protoreptilian animals the performance of these acts would be coordinated by the basal ganglia. In these forms the striatum is the highest center for sensory and motor processing, these functions being subserved by structures corresponding to the caudate/putamin and globus palladus, respectively (Schade' & Ford, 1973).

Stimulus and response are yoked in the protoreptilian brain. Since its repertoire of behaviors is unlearned (i.e., instinctive) this neural system "reacts to changes in the environment by increasing or decreasing the intensity of the predominant response sequence. . . . Suppression of response on the basis of non-reward or punishment is difficult" (Isaacson, 1974, p. 273).

The development of the paleomammalian brain allows the suppression of stereotyped ways of responding. The addition of the limbic system circuitry permits the organism to adjust its behavior based

on new sources of information about the internal and external environments and to utilize new and more efficient forms of learning in organizing its responding. It is important to appreciate that the final product of limbic system operations in the paleomammalian brain is the inhibition of lower centers. However, these same mechanisms later came to exert important influences on the neocortical systems.

The cerebral cortex of the neomammalian brain developed in close association with the limbic system and basal ganglia. New nuclei were added to existing sensory and motor systems, culminating finally in the arrangement now found in primates. More efficient information processing in the neocortical additions permits more precise sensory discriminations and rapid, fine-grain movements of the extremities (Isaacson, 1974) but these new systems still operate in close conjunction with the older subcortical mechanisms (Schade' & Ford, 1973).

The importance of the limbic system in human experience can hardly be overstated. These structures are implicated in most, if not all, forms of psychopathology. They are the probable substrate for the therapeutic effect of most psychotropic medications (Broekkamp & Lloyd, 1981) and the targets for all forms of "psychiatric surgery." Unfortunately, existing theory regarding the functional significance of the limbic system is primarily descriptive in nature or consists of generalizations so broad as to be of little use to the applied psychologist.

The Interpretation of Neurology Literature

The neurological data which form the basis of this review were gathered over many decades, from a variety of populations, by scientists with widely divergent theoretical beliefs. The psychologist who is unfamiliar with this literature must become aware of its inherent problems before venturing interpretations based upon it.

Those who come under the neurologist's care have, almost invariably, suffered a catastrophic change in their lives and personalities. Much of the data is drawn from individuals who have incurred brain damage as a result of a head wound, cerebrovascular accident (stroke), or cerebral tumor (neoplasm). While offering an otherwise unavailable opportunity to study higher brain functions, these devastating "natural experiments" invariably preclude the rigorous application of scientific method to that study.

Although techniques continue to improve, it is unusually impossible to define the parameters of a lesion accurately. Thus, crucial independent variables cannot be precisely isolated and controlled. Cause and effect interpretations are further hampered by the fact that a patient's pre-morbid level of functioning may be impossible to ascertain. Generalizability is also compromised when the subject has a chronic brain disease, such as epilepsy, or has undergone a surgical intervention to control that condition, such as temporal lobectomy or cerebral commissurotomy. In these cases, as with patients who have been subjected to "psychiatric surgery," it is reasonable to suggest that the "pre-treatment" psychological organization may have been grossly abnormal.

The human brain has remarkable ability to compensate for injury by utilizing undamaged tissue. This recovery of function in the time elapsed between injury and testing is a further confounding factor.

Much of this literature is in the form of case reports and the problem of individual variability is especially difficult to manage. Research designs utilizing groups and statistical analyses are becoming more frequent, but these studies invariably suffer from the difficulties noted above.

The most difficult problems to be encountered here have to do with the specification of dependent variables: "higher brain functions" tend to resist definition and to defy quantification. Generally, only gross operational definitions have been available. The physician/experimentor was often forced to resort to a judgement as to whether a given (and hypothetical) function was "intact" or "lost," with the attendant risks of experimentor bias and error. Related to this is the understanding, which emerged slowly in the development of this literature, that the function of a circumscribed anatomical area cannot be inferred directly from a deficit which follows the ablation of that area: one can only specify how the brain functions in the absence of that tissue.

Human Consciousness

Right versus Left

There have been three basic approaches to the study of lateralized cortical function: the comparison of patients with unilateral brain damage; the lateralized presentation of stimuli or task to the

sensory receptor fields of normal subjects; and the study of patients whose cerebral hemispheres have been surgically separated (Nebes, 1977). The early studies of split-brain subjects prompted a great deal of speculation about the abilities of the right hemisphere and a listing of the published works concerned with asymmetrical hemispheric functioning is beyond the scope of this paper. Evidence pertaining to the differences between the cognitive operations performed by the left and right hemispheres has been ably reviewed by a number of writers (e.g., Bogan 1969a, 1969b; Galin, 1974, 1977; Gazzaniga, 1970; Gazzaniga & Ledoux, 1977; Nebes, 1974, 1977; Sperry, 1968). Some of the more important differences will be noted very briefly here.

The primary deficits seen after right hemisphere lesions involve difficulties in perceiving, manipulating, and remembering spatial relationships and in perceiving and remembering sensory stimuli which resist verbal description (Nebes, 1977). The right hemisphere is superior to the left at generating a percept of the whole from fragmentary information and seems predisposed to notice complex gestalts or patterns rather than the parts (Nebes, 1971, 1974, 1977). The right hemisphere tends to process input simultaneously (in parallel) as opposed to the left hemisphere's preference for sequential (serial) processing, Cohen, 1973). In spite of many claims to the contrary, the evidence indicates that the right hemisphere considers only the immediately perceived context and performs its tasks in a reflexive, automatic fashion.

Language and the Left Hemisphere

The prominent Soviet geneticist, Theodosius Dobzhansky, observed that ". . . while all other organisms become masters of their environments by changing their genes, man does so mostly by changing his culture, which he acquires by learning and transmits by teaching" (Dobzhansky, 1964, p. 145). Cultural evolution was made possible by the development of language, but language is more than a special form of social communication by which culture is transmitted: it is the mechanism which produces the adaptive behavior patterns that released the species from the constraints of biological evolution. Speech is the fundamental tool of intellectual activity. Language processes are essential in the operations of abstraction and generalization, the basis of categorical thinking, and the vehicle for organizing and regulating mental processes and behavior (Luria, 1973).

The clearest example of functional brain asymmetry is the lateralization of language to the left hemisphere, a fact long established by two observations: deficits in language functions (aphasia) following damage to the left hemisphere and the retention of language following right hemisphere injury (right handedness is assumed throughout the text unless otherwise noted). The patterns of language deficit following circumscribed lesions provide the most concrete evidence that is available about the mechanics of consciousness and its product, cognition. The focus of the following review is not on language itself, but on the evidence which indicates that the active operations of consciousness which produce

adaptive behavior are part of a functional system that is lateralized in the left hemisphere of the brain.

Aphasia: Anatomy and Syndromes

Three general types of aphasia have been defined and traced to different anatomical structures in the left hemisphere. Through an analysis of these syndromes it is possible to deduce the outline of a functional system in which these separate areas work together to produce the complex function of language. The following summary is based on reviews by Gardner (1975) and Zaidel (1978).

Broca's aphasia, resulting from damage to the inferior, post-frontal zones of the left hemisphere, is an expressive disorder. Utterances are difficult to initiate and speech is painfully slow and labored. Patients are usually able to name objects and to repeat, having less trouble with words that are familiar and concrete. Although they manage to convey their meanings in a peculiar, "telegraphic" style, they are unable to produce a fully formed sentence. Their productions consist almost entirely of substantives; grammatical parts and forms are absent or impoverished. Nouns are usually delivered in the singular and verbs appear in their simplest, noninflected form. Parts of speech that are purely grammatical in function (conjunctions, prepositions, articles, adverbs) are exceedingly uncommon. The same deficit pattern is evident in the patient's reading and writing.

Although patients with Broca's aphasia may have difficulty in unravelling complex grammatical relationships (e.g., "The lion was eaten by the tiger: which animal is dead?"), their comprehen-

of language is generally intact. The ability to understand and utilize nonverbal symbolism (e.g., gesture, pantomime) is also spared. Intellectual functioning is relatively unimpaired. Patients retain the ability to reason logically, to abstract and to generalize, and to respond to context appropriately. Their associational processes are not loosened, tangential or pressured. They do not produce paraphasias or confabulate. Finally, these patients are acutely aware of their deficits; they may be appropriately depressed and are prone to sudden, transient emotional outbursts.

Exactly the opposite clinical picture is evident when Wernicke's area, on the lateral, convex surfaces of the left temporal lobe, is damaged. Wernicke's aphasia is characterized by impaired language comprehension with fluently articulated but nonsensical speech. Unlike the Broca's aphasic, words are spoken clearly with normal sounding cadence, intonation and melody (prosody). However, the speech of the Wernicke's aphasic is lacking in content and may consist almost entirely of semantic jargon which has little communication value. These patients appear to have lost control of the language mechanisms at all levels. It is as if the selection thresholds for phonemes, words, and ideas were all lowered. Repetition is poor and marked by paraphasic errors in which the correct sounds may be present but emerge in the wrong order. Patients are able to name only the most familiar objects accurately, although the word produced may come from the same category as the target. Prompting with the initial wordsounds seldom helps.

In spontaneous speech the key substantives are often missing and the remaining parts of speech lack their organizing influence. Grammatical parts and forms are used abundantly but incorrectly. Adjectives, adverbs, conjunctions and prepositional phrases are strung together haphazardly and the result may resemble a schizophrenic's "word salad" (Luria, 1973). Nonsense syllables and neologisms are frequent. The guiding thought behind a verbal production may be evident, but it becomes obscured by tangential associations and incomprehensible babbling.

The Wernicke's aphasic understands little of what is said and seems to rely on nonverbal cues in order to respond to a situation. They are also unable to comprehend nonverbal symbolism and so their communication is vague and concrete at all levels.

Perhaps the most striking feature of Wernicke's syndrome is the patients' complete lack of awareness of and indifference to their deficits. They appear unconcerned and will vehemently deny any problems.

The same deficits are evident in reading and writing tasks. The patient can read single words but does not seem to grasp their meaning or relate them to him or herself. They may correctly repeat a simple command written on a card but will make no attempt to comply. Unable to formulate an acceptable sentence on their own, they are able to arrange cards with words printed on them to form a syntactically correct sentence. However, the key substantives are likely to be misplaced (e.g., "The man bit the dog.") confirming again that the patient's facility is with grammar as opposed to meaning.

There is less agreement about the third major language disorder, known as anomic or amnesic aphasia, which results from more posterior lesions located in the angular gyrus in the parieto-occipital area. Part of the confusion may stem from the fact that its main symptom, the loss of the ability to name objects, is common to all aphasic disorders. However, the anomic aphasia syndrome is distinguished by the fact that the naming disorder is accompanied by relatively intact comprehension of written and spoken language and normal spontaneous speech. The ability to read and to repeat are also spared in anomic aphasia.

The anomic aphasic has no difficulty using words in their appropriate context but cannot find the word in isolation of context; he is unable to divorce himself from the immediate situation. The anomic aphasic cannot produce the name of objects on demand even though he knows what they are. When an object is designated the patient is unable to produce its name, and conversely, given a name, the patient is not certain what it refers to.

Other language difficulties are evident. The patient's spontaneous speech seems to be either too detailed or too general. Thinking is very concrete; the patient will interpret proverbs literally. The patient is aware of the disabilities and will often develop strategies to compensate for them.

Language, Symbolism, and Meaning

The theory of the functional organization of language developed by Wernicke in 1885 is still generally accepted today. According to this model the underlying structure of an utterance arises in

Wernicke's area. It is then transferred via large fibre bundles (the arcuate fasciculus) to Broca's area where it evokes a detailed program for vocalization which is governed by the rules of grammar and syntax. The program developed in Broca's area, the linear scheme of the sentence, is supplied to the adjacent face area of the motor cortex which in turn drives the muscles which produce the vocalization. Thus, the content of speech originates in Wernicke's area and finds its form in Broca's area.

Wernicke's area is also essential for the comprehension of language. Auditory stimuli are relayed from the Organ of Corti to the primary auditory projection areas in Heschl's gyrus in the left temporal lobe. At this point, as with the other sensory projection areas, the information is somatotopically organized and retains its modal specificity; to be understood it must be transferred to the secondary auditory association area (Wernicke's area) where the somatotopical organization is converted into a functional organization (Luria, 1973a). Here, the fundamental phonemic characteristics of language are isolated and identified. Processing by Wernicke's area is essential for both the encoding and decoding of meaning. An intact Wernicke's area is also essential for the expression and comprehension of meaning through symbolic gesture and pantomime (Goodglass & Kaplan, 1973; Gionotti & Lemmo, 1976). It is interesting to note in this regard that "illusions of interpretation" emerge in consciousness after electrical stimulation of the temporal lobe in the right hemisphere but not after stimulation of any other brain area (Mullan & Penfield, 1959).

Human Consciousness, Self-Awareness, and Thought

In the 1960s the general belief in cerebral dominance gave way to the idea of cerebral specialization due, in large part, to the "split-brain" studies conducted on the cerebral commissurotomy patients of Drs. Vogel and Bogan. In 1969 Bogan took the progression a step further when he revived Wigan's (1844) notion of "the duality of mind." Wigan (noting the anatomical duality of the brain, autopsy findings of hemispheric atrophy in patients whose personality was apparently intact, and introspective evidence of concurrent, opposing trains of thought) argued that if one hemisphere can sustain a mind, "it necessarily follows" that a man with two hemispheres must have two minds (p. 271). Bogan endorsed this concept in the third of his influential "Other side of the Brain" papers (Bogan, 1969a) and concluded that

Pending further evidence, I believe (with Wigan) that each of us has two minds in one person. . . . Various kinds of evidence, especially from hemispherectomy, have made it clear that one hemisphere is sufficient to sustain a personality or mind. We may then conclude that the individual with two intact hemispheres has the capacity for two distinct minds. This conclusion finds its experimental proof in the split-brain animals who can be trained to perceive, consider, and act independently. (1969, pp. 156-157)

The "dual mind" concept implies two relatively equal but functionally independent entities which act as opposed forces in the process of determining behavior. Bogan contributed the hypothesis that the two hemispheres utilize different "modes of thought" in this process: "propositional" on the left and "appositional" on the right (1969, p. 160). These appealing ideas were enthusiastically

embraced by laymen and professionals alike. They have been cited to support all manner of theories concerning psychological, philosophical, and spiritual dualities (see the critique by Kinsbourne, 1982). However, a closer analysis of the data cited by Bogan suggests that such conclusions are misleading.

Michael Gazzaniga, an author of the pioneering animal studies referred to by Bogan as perhaps the most dedicated and prolific of the "split-brain" researchers, complained about the "overpopularization" of basic data produced by himself and his colleagues:

These popular psychological interpretations of "mind left" and "mind right" are not only erroneous: they are inhibitory and blinding to the new students of behavior who believe classic styles of mental activity break down along simple hemispheric lines. (1977, p. 416)

There is no doubt that one cerebral hemisphere can, in the absence of its counterpart, support high level intellectual activity if the loss of the other hemisphere occurs early in development. Griffith and Davidson (1966), for example, report that children show relatively good recovery from hemispherectomy for infantile hemiplegia.

Smith and Sugar (1975) reported on a 26 year old man who showed superior intelligence (WAIS VIQ:126, PIQ:102, FSIQ:116) 21 years after undergoing left hemispherectomy at age five and one-half. However, it is improper to infer normal functioning directly from grossly abnormal cases such as this, or from animal studies. While it is clear that the right hemisphere may have the capacity to develop higher mental processes, there is no evidence that it does so normally, and considerable evidence to the contrary. Research

efforts in this area have been hampered by the lack of adequate operational definitions (for such phenomena as consciousness, cognition, and thought) which distinguish the hither mental processes of humans from the brain functions of lower forms.

Cerebral dominance for consciousness has been investigated using the Wada carotid amobarbital test, a procedure developed to localize language functions prior to neurosurgery. The Wada test involves injecting sodium amobarbital into one common carotid artery and results in the anesthetization of only the cerebral hemisphere on the side of the injection. Terzian (1964) reported an absolute and immediate arrest of any communication, both verbal and nonverbal, in the first thirty to sixty seconds after the injection of the drug into the carotid artery of the dominant side which he interpreted as a transient loss of consciousness. Serafetinides and his co-workers reported similar results and noted that the phenomenon rarely occurred following barbiturization of the non-dominant hemisphere (Serafetinides, Driver & Hoare, 1964, 1965a, 1965b). They concluded that unconsciousness, and by implication consciousness, is in general linked with the function of the hemisphere dominant for speech (Serafetinides et al., 1965a).

Rosadini and Rossi (1967) attempted to replicate these findings using more strictly operationalized definitions of consciousness. In one group (48 cases) the criteria consisted of an "analysis of the capacity of the patient to keep in contact with the examiner through verbalizations or movements, to react to noxious stimuli

and to describe at the end of the examination what happened during the examination itself" (p. 103). In a second group the criteria for consciousness consisted of "a simple stimulus-response test" in which "the patients were instructed to work a switch held in the hand ipsilateral to the intracarotid injection [i.e., the hand controlled by the unanesthetized hemisphere] any time they heard a given sound or saw a flash of light" (p. 103). Behavioral and clinical events indicating unconsciousness were required to last more than one minute in order to "permit their safe detection." They found that 47 of their 69 cases did not meet their criteria for unconsciousness and the 22 cases which did occurred in roughly the same percentage following left and right injections; aphasia occurred in 16 cases (15 left, one right); only five of the 21 cases (three left, two right) evaluated with the stimulus-response test failed to operate the switch held in the hand controlled by the unanesthetized hemisphere in response to the signals used. Although their results were complicated by existing neuropathological and cerebrovascular abnormalities, these authors concluded that "the existence of a cerebral dominance for consciousness is not supported" (p. 111). The usefulness of this study appears to be severely limited by the criteria used to evaluate consciousness in the unanesthetized hemisphere: a large number of animals of various species have demonstrated the ability to "work a switch" in response to visual and auditory stimuli and to respond to noxious stimuli, but these lower forms are not considered conscious in the same sense that humans are. The authors were looking for "the

occurrence of signs revealing the capacity of the subject to keep in contact with the external world" (p. 103). They acknowledged that "the suppression of expressive and receptive speech functions make such a task quite difficult with the patients receiving barbiturate in the dominant hemisphere" (p. 109). It seems that it is only the appearance of aphasia (after dominant hemisphere anesthetization) that is specific to human consciousness in this study, and these findings are consistent with those of Terzian and Serafetinides et al.

Rosadini and Rossi did not report the results of their test of subjects' ability to recall what had occurred during the Wada procedure but this question was addressed directly in an experiment reported by Gazzaniga (1977). This author found that "information encoded while the left hemisphere was anesthetized was uninterpretable by the verbal system when the left hemisphere returned to normal functioning . . . when information is encoded by other than the verbal system the person is not consciously aware of the information" (p. 150).

Another approach to the localization of conscious awareness involved an analysis of the temporal discrimination for simultaneity when two visual stimuli were presented separately to the left and right visual half-fields, separated by a very brief interval. Efron (1963a; 1963b) found that normal right-handed subjects reported that the two flashes occurred simultaneously only when the light flashed in the left visual half-field was presented several milliseconds earlier than the light flashed in the right visual field.

Efron argued that this was because the "conscious comparison" of the two flashes takes place only in the hemisphere dominant for language, the time lag representing the extra neural steps involved in relaying sensory information from the right hemisphere over the corpus callosum:

It is only after sensory data have reached the left hemisphere that one is "conscious" of the occurrence of an event. . . . To be conscious of something is to be conscious of something now. It is the thesis of this paper that the "now" is the moment of arrival of sensory data in the dominant temporal lobe. (1963b, p. 421)

The most convincing evidence of a correlation between human consciousness and language ability emerged from studies of a unique cerebral commissurotomy patient known as "case P.S." P.S., a right handed boy, developed epilepsy following an injury to his left hemisphere incurred at age two. He subsequently developed language skills in both his right and left hemispheres. At age 14 he underwent complete surgical section of his corpus callosum to relieve his epilepsy. Following surgery it was found that P.S.'s right hemisphere could spell, comprehend verbal commands, process parts of speech and make conceptual judgements involving verbal information. It was also discovered that his right hemisphere, although unable to speak, could generate answers to printed questions presented tachistoscopically to his left visual half-fields. He accomplished this by arranging Scrabble letters with his left hand. These answers were often different from those given verbally by his isolated left hemisphere. Gazzaniga and Ledoux (1977) argued that P.S.'s right hemisphere possessed qualities deserving of conscious status because.

His right hemisphere has a sense of self, for it knows the name it collectively shares with the left. It has feelings, for it can describe its mood. It has a sense of who it likes and what it likes, for it can name its favorite people and its favorite hobby. The right hemisphere in P.S. also has a sense of the future, for it knows what day tomorrow is. Furthermore, it has goals and aspirations for the future, for it can name its occupational choice. . . . The fact that this mute half-brain could generate personal answers to ambiguous and subjective questions demonstrates that in P.S. the right hemisphere has its own independent response-priority determining mechanisms, which is to say, its own volitional control system. (pp. 143-145)

P.S. is the only split-brain patient with advanced language skills in his right hemisphere and the only patient to demonstrate double consciousness. Ledoux, Wilson and Gazzaniga (1977) stressed the fact that "in all other patients, where linguistic sophistication is lacking in the right hemisphere, so too is the evidence for consciousness" (p. 420).

The capacity for speech and conceptual thought is clearly innate in homo sapiens; only the symbols themselves must be learned (Campbell, 1974). Recent evidence has clarified the anatomical substrate of this genetically transmitted specialization. The development of language capabilities in the human species is correlated with the anatomical expansion and interconnection of the association areas in the left hemisphere (Campbell, 1974). The posterior area of the planum temporale, which forms a part of the secondary auditory cortex (Wernicke's area) is significantly larger on the left side (Geschwind & Levitsky, 1968). The enlargement of this area can be explained in terms of its distinctive cellular organization (Galaburda, LeMay, Kemper & Geschwind, 1978) and the

incomplete development of this cellular architecture has been related to language dysfunction (see Geschwind, 1979).

In her exhaustive study of hundreds of brain injured war veterans, Semmes (1967) discovered that elementary sensory and motor capacities were focally represented in the left hemisphere and diffusely represented in the right. She proposed that this difference indicates the mechanism of hemispheric specialization: focal organization favoring fine control and the integration of similar units (e.g., manual skills and speech) and diffuse organization favoring multimodal coordination (e.g., the various spatial abilities).

Gazzaniga and Ledoux (1977) observed that nearly every demonstration of a right hemisphere advantage in split-brain patients has involved manipulo-spatial activities and concluded that

[This advantage] exists so long as manipulative activities are involved in either the stimulus perceptions or the response production. . . . The probable neural substrate of these manipulo-spatial acts involves the inferior parietal lobule of the right hemisphere in humans. In the left hemisphere, however, linguistic functions occupy the inferior parietal lobule. . . . The superior performance of the right hemisphere of split-brain patients on such tasks does not reflect the evolutionary specialization of the right hemisphere, but instead represents the price paid by the left hemisphere in acquiring language. . . . Our view is not that the right hemisphere is specialized in some unique way in man. Rather, it continues to do what it does elsewhere in the phyla. (pp. 420-421, emphasis added)

Campbell (1974) noted that "spatial relationships involving depth and distance may appear to be predominately spatial concepts, but they are not of space but about space; of themselves they are spaceless and concerned with pattern rather than place" (p. 337).

It appears, then, that the left hemisphere extracts meaning from the relationship of individual parts to each other, while the right gathers meaning from the pattern of the whole.

Bogan (1969b) proposed that the right "mind" utilized a different mode of thought which he characterized as appositional to denote the ability to appose, or compare, information. He contrasted this with the propositional mode utilized by the left hemisphere. A number of investigators have distinguished similar dichotomies of information processing style. Luria (1973a) spoke of narrative versus relational processes. Galin (1974) suggested that the right hemisphere solved problems through a process of multiple converging determinants as opposed to a left hemispheric style which utilized a single causal chain. Sechenov (quoted by Luria, 1973a) postulated that the human brain utilizes two forms of integrative activity: organization into simultaneous and primarily spatial groups, and into temporally organized successive series. This is consistent with Spearman's conclusion that intelligence comprises two components: the eduction of correlates used in analogical reasoning and the eduction of relations, the basis of abstract reasoning (see McFie & Piercy, 1952). Campbell (1974) noted that "abstraction means escape from the present . . . what distinguishes man from animals is the length of time through which his consciousness extends (p. 335). Finally, Bogan (1969b) observed that the most important distinction between the left and right hemispheric modes might be "the extent to which the linear concept of time participates in the ordering of thought" (p. 160).

There is a clear consensus recognizing two modes of information processing. However, the ability to process information is not necessarily a sufficient condition for consciousness. Although the notion of right brain "thought" has gained wide currency, to date, there has been no conclusive evidence that any cognitive operation occurring in the right hemisphere is directly experienced in consciousness. A possibility not considered by any of the above authors is that one mode might be an ancillary resource utilized by the other. The data reviewed thus far suggests that one must be very careful to avoid anthropomorphizing when attempting to describe right brain processes. However, some inductive conclusions may be drawn.

Discussion

It is evident that human consciousness is inexorably linked with the abstract symbolic processes associated with language. Perhaps the most universally accepted characteristic of human thought is self-awareness. Self-awareness (and its product, the self-concept) requires the abstraction and appreciation of defining features which are consistent over time and situation. Only the left hemisphere, with its temporal acuity, can consider and appreciate changed or conserved relationships in different conditions or contexts. Thus, only the left hemisphere can define itself. The resulting self-awareness provides a reference point for all of the memories, feelings, intentions and thoughts that are collectively known as the mind and which allow the individual, thus defined, to interact intelligently with the environment. Lacking the temporal organizing skills to

construct such a consistent frame of reference the right hemisphere is bound to the immediate context with only the influences of the physiological status of the organism (and the left hemisphere) to guide its processes. Complex motivations, therefore, cannot exist in the right hemisphere. Likewise, so-called "pictorial thinking," if temporally ordered and goal directed, must be organized by the left hemisphere. Galin (1974) suggested that the context bound, egocentric and impulsive nature of right hemisphere cognition resembled Freud's notion of primary process thinking. Higher mental processes in the right hemisphere almost certainly qualify as cognitions (i.e., a way of knowing) and may account for the phenomenon of intuition (knowledge without awareness of the process by which it was gained). However, the term "thought" seems misleading and "information processing" might be preferable. As noted above, there is no direct evidence that mental events occurring in the right hemisphere are directly experienced in the conscious left hemisphere; one is left to ponder the question of whether a tree falling in the right brain would make a sound if the left wasn't listening.

The restrictions outlined above are in no way inconsistent with the demonstrated role of the human right hemisphere in the analysis of emotional communications and the modulation of affective expression (e.g., Ross & Mesulam, 1979). The brains of lower forms (and, apparently, the right brain in humans) are primarily concerned with neuronal signals which represent the survival needs of the organism within the immediate environment. Interaction with

the social environment is critically important to survival throughout the phylum. Campbell (1974) noted that animal vocalizations and signals are "emitted only in the presence of the appropriate stimulus" (p. 349) and warned against equating these vocalizations with human speech: "the signals . . . are generated or motivated by the phenomenon of emotion, and find their neurological origin not in the cortex but in the limbic system of the brain" (1974, p. 348). The cortical organization of these functions in the right brain of humans appears to mirror that of language in the left hemisphere with comprehension and expression utilizing anatomical areas homologous to Wernicke's area and Broca's area, respectively (Ross & Mesulam, 1979). Right hemisphere responses might achieve direct expression in circumstances where control by Broca's area in the left hemisphere is impaired or attenuated, a case in point being the clearly enunciated emotional exclamations of the frustrated Broca's aphasic. Similarly, poorly defined and undifferentiated emotionally generated behavioral impulses (e.g., approach, avoidance) might also achieve motor expression in the absence of adequate left hemisphere control.

Hughlings Jackson (1864) suggested that if the "faculty of expression" was proven to be lateralized in the left cerebral hemisphere it would then be reasonable to expect that its corresponding opposite, perception, might be lateralized to the right. Although the concept of mental "faculties" has given way to an appreciation of complex functional systems, the role of the right hemisphere within those systems might, in a broad sense, be said to conform to Jackson's prediction. While the information processing

style of the right hemisphere is not suited to solving problems or making decisions, it is uniquely qualified to perceive the quality of significance (as defined by the individual's experience) in complex environmental stimuli. The evidence suggests that the human right hemisphere attends to the overall pattern of stimuli, searches out ("apposes") associations which are correlated with important stimulus configurations and collates them into percepts that have meaning for the organism. Its associational processes are unencumbered by rules of logic and its perceptions uninfluenced by expectations.

The thrust of Bogan's (1969b) "dual mind" thesis was a reaction against the traditional concept of hemispheric dominance which relegated the right hemisphere to the role of an "automaton" or reserve organ (e.g., Henschen, 1926; Strong & Elwyn, 1943). A basic assumption in the present work, however, is that evolutionary pressures required in the development of an automatic environment monitoring system in order to permit the transition from instinctual to self-determined behavior. It appears that evolution solved this problem by taking advantage of the fact that the human central nervous system contains two relatively autonomous brains which could be yoked together by the limbic system. Within this configuration the left hemisphere may be seen as a problem-solving and response-generating system and the right hemisphere might be said to function as the repository and librarian of the individual's reinforcement history.

Cortical Mobilization: Attention, Arousal, and Activation

Consciousness and cognition become possible only when minimum levels of cortical tone are attained. These tonic levels, reflected in the desynchronized EEG pattern, permit sensory discriminations, motor acts and other cognitive operations to take place. Once activated, the cortex has the ability to make phasic modifications of its level of activity and to voluntarily direct its attention. The fundamental systems which govern cortical tone and attention, however, are automatic and capable of overriding voluntary controls. It is clear that these systems, with their ability to control the level and content of consciousness, will exert a significant influence on the personality structure.

The Reticular Activating System and Tonic Arousal

The mobilization of the cortex is accomplished by the brainstem reticular formation (RF). This structure is a network of highly interconnected neurons which adjusts its level of activation by integrating input from the sensory pathways, limbic system structures, and the neocortex. Impulses from the reticular formation lower the activation thresholds of the neurons it projects to. When the reticular formation is relaxed, cortical tone is lowered and the organism sleeps (Moruzzi & Magoun, 1949).

The reticular activating system (RAS) regulates the state of activation of the brain in two ways: the ascending reticular activating system (ARAS) affects the brain diffusely and sets the generalized (tonic) level of arousal; descending influences direct

RAS impulses to accomplish localized (phasic) arousal of specific areas of the brain. The ascending pathways of the RAS project rostrally from the brainstem reticular formation (via the central tegmental tract/medial forebrain bundle) to the hypothalamus, septal area, and nonspecific intralaminar thalamic nuclei (ILTN). The second path extends from the interpeduncular nucleus to the ILTN via the habenula. The only direct ascending connections from the RAS to the neocortex are projections from the nonspecific thalamic nuclei (midline and ILTN) to the orbitofrontal cortex (via the ventral anterior nucleus of the thalamus). Descending influences are conveyed from the prefrontal neocortex to lower structures by way of the thalamocortical radiations, corticoreticular fibers, medial forebrain bundle, and thalamotegmental fibers. Hippocampal output reaches the reticular formation via the fornix, mammillary bodies, and mammillotegmental tract. The septal area has an additional connection with the reticular formation by way of a stria terminalis--habenula--habenulointerpeduncular tract--interpeduncular nucleus pathway (Noback & Demerest, 1972).

Based on their analysis of some 200 experiments, Pribram and McGuinness (1975) outlined two major subsystems in the brainstem which control cortical mobilization and identified separate forebrain mechanisms which modulate their functioning. These systems initiate two different types of cortical activity. Diffuse cortical "arousal," which is associated with the orienting response, is based on the serotonergic brainstem median raphe nuclei located in the core of the reticular formation. Arousal is modulated by

a lateral-frontal--amygdala--lateral-hypothalamus facilitory circuit and an inhibitory orbitofrontal--amygdala--medial-hypothalamus circuit. "Activation" is an attention focusing process involved in perceptual expectancies and motor readiness to respond. This system is based on the locus ceruleus, in the periaqueductal gray, which supplies norepinephrine to the forebrain. Activation was thought to be modulated by the ancient motor control system in the basal ganglia. Together, these systems provide for appropriate attending to novel or significant stimuli and prepare the organism to respond cognitively and behaviorally. The hippocampus was seen to integrate the functioning of these systems and to exert ultimate control over cortical mobilization through a mutually inhibitory relationship with the reticular formation.

Phasic Control Systems: The Frontal Lobes and Thalamus

A novel (possibly significant) stimulus elicits an orienting response (OR) from the organism. The psychological phenomena associated with the OR are familiar to all who have had experience with "things that go bump in the night." The complete orienting reaction includes

The suppression of ongoing behavior, the orienting of the body and receptor towards the new stimulus, changes in the peripheral autonomic nervous system, and, perhaps less obvious, preparations for associating the new stimulus with memories from the past and expectancies of the future. (Issacson, 1974, p. 110)

Pribram (1973) noted that the stimulus sampling aspects of the orienting response differed from the processes necessary to register a stimulus in awareness and memory (which must be accomplished

before the organism can habituate to a stimulus). In contrast to the indiscriminate arousal associated with orienting, these latter processes require the focusing of attention.

The mobilization of selective attention ("activation") appears to be reflected in the contingent negative variation (CNV) or "expectancy wave" (Tecce, 1970). The CNV is a special form of cortical evoked response which consists of a spreading wave of negative potential that appears whenever there is a contingent relationship between two stimuli. Negativity develops when brain tissue is maintaining a readiness for processing (Pribram & McGuinness, 1975). Thus, the CNV appears whenever the organism is expecting to perform a perceptual or motor act. The negativity becomes abruptly positive when that act is executed (Walter, Cooper, Aldridge, McCallum, & Winter, 1964). High amplitude CNVs are related to greater efficiency of perceptual and motor responses; concentration facilitates the CNV while inattention, boredom, or fatigue decrease it (Cohen, 1974). Elithorn et al. (1958) postulated that frontal lobe injuries somehow damaged the mechanism underlying anticipatory sets. It is interesting, in this light, that the CNV generally appears in the prefrontal lobes and sweeps posteriorly over the post-central cortex.

Patients with frontal lesions are unable to sustain their attention. While intelligence, as measured by standardized tests, may be unimpaired, these individuals are highly distractable and cannot carry out purposeful activity which is normally directed by intentions (Luria, 1973a). Luria pointed out that patients with

lesions of the temporal, parietal, or occipital lobes may have sensory, orientation, or intellectual deficits, but their attention and concentration remain sustained and directed by intentions. Luria and his co-workers suggested that the frontal syndrome reflected the loss of this selectivity (Luria, Homskaya, Blinkov, & Critchley, 1967). An understanding of the functioning of thalamic systems suggests a mechanism by which the frontal lobes might select or "recruit" psychological operations in the post-central cortex.

The thalami are a pair of egg-shaped masses located beneath the cortex in the center of the cerebral hemispheres. The thalamus is the final processing point for cortical input and the central integration station of the nervous system. The brief review of thalamic anatomy and functioning presented below is based on reviews by Noback and Demerest (1972) and Chusid (1976).

The ventral half of the thalamus contains the specific relay of nuclei of the sensory-motor systems. The nuclei of the dorsal tier are association nuclei which have reciprocal connections with the association areas of the post-central cortex and no sub-cortical connections; the dorsolateral and posterolateral nuclei are interconnected with the parietal lobe, and the pulvinar with the temporal and parietal lobe.

The dorsomedial and anterior thalamic nuclei are association nuclei involved in emotion and memory, respectively. The dorso-medial nucleus receives input from the amygdala and lateral hypothalamus and has reciprocal connections with the association areas of the prefrontal lobe. The anterior nuclei of the thalamus receive

the output from the hippocampus and have reciprocal connections with the cingulate cortex.

Lying between and separating the major thalamic association nuclei, the nonspecific (intralaminar, midline and reticulate) nuclei have only intrathalamic and subcortical connections. They receive their main input from the brainstem reticular formation and from the rostral end of the ascending reticular activating system (ARAS). The intralaminar nuclei have the "remarkable property of being able to exert a controlling influence upon the rhythmic electrical activity of the entire cortex" (Jasper, 1949, p. 406). Jasper noted that this system is in a position to provide a central coordinating mechanism for cerebral activities:

A central integrative mechanism with ready access to all afferent and elaborative systems of both hemispheres, and closely related to autonomic spring of action; is necessary to explain consciously directed thought and behavior. It seems that the thalamic reticular system, with its diffuse cortical projections, relations to afferent and efferent systems, relations to mesencephalic hypothalamic and striatal systems, is a good candidate for this office. (Jasper, 1949, p. 419)

Discussion

The brain's mobilization systems with their brainstem, thalamic, and forebrain components, regulate consciousness, unconsciousness, and the differential consciousness of attention. Sensory signals representing possibly significant stimuli cause the reticular formation to initiate diffuse cortical arousal. When a stimulus has been identified, cortical activation systems facilitate the organization of cerebral activity to deal with the situation appropriately. It appears that the frontal lobes direct this process

by recruiting psychological operations in the post-central cortex. The frontal lobe may accomplish this through its influence on the nonspecific thalamic nuclei which, in turn, control the phasic activation of specific cortical systems.

It is important to note that the two biochemically mediated subsystems which control the mobilization processes are duplicated in both halves of the brain. Unilateral prefrontal lobe lesions have been found to produce deficits which resemble those seen after damage to post-central lesions on the same side: right frontal lesions have been associated with disturbances of emotion and spatial abilities while left-sided injuries lead to disorders of speech and thought (Zangwill, 1966; Benton, 1968; Luria, 1973a). Processes which disrupt the biochemical balance between the two control mechanisms have far-reaching psychological consequences which will be reviewed in a later section.

Motivation: Emotion and Affect

The greatest risk involved in giving up instinct-based responding in favor of self-determined behavior is the possibility that the individual might fail to respond appropriately in survival-related situations. The evolution of the species could not have occurred if this problem had not been solved. The forces which motivate adaptive behavior must, by definition, be the single most powerful influence on the personality structure. The evidence indicates that the source of these forces lies in the limbic system. It appears that separate cortical mechanisms mediate their internal experience and external expression.

Amygdala Circuits and the Prefrontal Lobes

The role of the amygdala in emotional processes established by Kluver and Bucy in 1938, has been assumed to be affected through this structure's close relationship with the hypothalamus. The amygdala seems to direct behavior toward biological goals (Halgren, 1981) and is implicated in the control of species-specific behaviors related to survival needs, including defensive and aggressive behaviors, sexual activity, and feeding (Isaacson, 1974). In lower forms these processes might depend on a simplified (instinctive) form of memory in which stimulus and response are yoked (Pribram & McGuiness, 1975). In addition to mediating emotional states the amygdala is involved in the analysis of reinforcement contingencies. Amygdala lesions have been shown to produce impaired recognition of stimuli associated with rewards (Weiskrantz, 1956; Schwartzbaum, Thompson & Kellicut, 1965; Jones & Mishkin, 1972) and inability to respond appropriately to changes in the magnitude of rewards (Schwartzbaum, 1960).

Strong interconnections with the hypothalamus (via the stria terminalis and ventral amygdalofugal fibers) give the amygdala immediate access to information concerning the internal status of the organism (Price, 1981). The amygdala also receives processed sensory information from all of the secondary sensory association areas (Van Hoesen, 1981). Mishkin and Aggleton (1981) noted that this arrangement places the amygdalae in a position to integrate external events with their internal consequences, which would permit the attachment of emotional and motivational significance

to sensory stimuli. Kessner (1981) reported experimental evidence that demonstrated the essential role of the amygdala in encoding and retrieving the positive and negative attributes of a specific memory. In lower forms the identification of a motivationally significant stimulus might result in the release of species-specific behaviors, but in humans behavior is self-determined. Halgren (1981) concluded from his amygdala stimulation studies with humans that "the amygdala helps organize the discharge of emotional tension into consciousness" (p. 404) and noted that this would allow the directing of consciousness toward biological goals. The amygdala's input to the neocortex is directed to the entire prefrontal lobe both directly, via the uncinate fasciculus, and indirectly, by way of the dorsomedial thalamus (Noback & Demerest, 1972; Price, 1981).

While damage to the dorsolateral area of the prefrontal lobes has been associated with intellectual disturbances, lesions of the orbito-frontal cortex (and orbital undercutting, which disconnects this area from the amygdala) result in emotional changes (Lewin, 1961). Elithorn, et al. (1958) concluded that this type of damage produced a "generalized impairment of the ability to form appropriate emotional responses" (p. 250), including the ability to elaborate on the affect appropriate to the concepts present in consciousness.

In contrast to the planning deficits, loss of energy and interest, and affective dullness seen after dorsolateral frontal damage, orbito-frontal injuries often lead to euphoria, impulsive (disinhibited) behavior, and the appearance of "greediness, selfishness, and

tactlessness" (see Lewin, 1961). Faust (1966) noted that such patients resemble psychopaths in that they are unable to profit from experience and are in constant conflict with their environment and the law. Zangwill (1966) pointed out that the tactlessness common in frontal lobe patients does not result from a loss of knowledge of social conventions, but from the failure to regulate behavior in accordance with those standards.

Disconnecting the orbito-frontal cortex from the amygdala (orbital undercutting) has been reported to be the most effective psychosurgical operation for relieving the symptoms of anxiety and depression (Elithorn et al., 1958; Lewin, 1961; Levinson & Meyer, 1965). Elithorn et al. (1958) noted that this procedure increased reactions of "a hysterical type" and is contraindicated for those conditions. It is interesting to note that drugs that reduce anxiety and produce euphoria (e.g., the barbiturates) have been found to exert an uncoupling effect between the frontal lobes and the limbic system (Heath & Galbraith, 1965).

Affective Expression

The right hemisphere plays an essential role in both the comprehension of emotional communications and the expression of affect. Patients with right hemisphere lesions showed impaired recall of stories with emotional content versus neutral stories (Wechsler, 1973). Hielman, Scholes and Watson (1975) demonstrated that judgements of the emotional mood of a speaker (sad, happy, angry, indifferent) made by patients with right temporoparietal lesions were significantly impaired relative to patients with left-sided lesions and controls. This finding was replicated by Tucker,

Watson and Hielman (1976) who showed also that right hemisphere patients were impaired in the vocal expression of emotion. The efforts of patients with right temporoparietal damage to impart a sad, happy or angry tone to their voices were rated as incorrect significantly more often than controls. Ross and Mesulam (1979) presented case studies of two well-educated patients who had comparable damage in the right supra-sylvian area, which is homologous to Broca's area on the left side. Both patients showed flattened affect and had completely lost the ability to laugh, cry, or otherwise express any emotion in their speech. Their ability to experience and comprehend emotions was unchanged. The authors noted that the organization of emotion in the right hemisphere seems to mirror that of language in the left: the area homologous to Wernicke's area being essential for comprehension, and to Broca's area, for expression.

Gazzaniga and Ledoux (1977) suggested that right hemisphere functioning in humans is distinguished only by contrast to the left; it continues to perform its functions in the same manner as elsewhere in the phylum. Although it should be noted that the human right hemisphere is in possession of tertiary association areas and so would perform those tasks more efficiently, the data reviewed above are not inconsistent with Gazzaniga's interpretation. The brains of lower forms (and, apparently, the right brain in humans) are primarily concerned with neuronal signals which represent the survival needs of the organism within the immediate environment. Interaction with the social environment

is critically important to survival throughout the phylum. Campbell (1974) noted that animal vocalizations and signals are "emitted only in the presence of the appropriate stimulus" (p. 349) and warned against equating these vocalizations with human speech: "the signals . . . are generated or motivated by the phenomenon of emotion, and find their neurological origin not in the cortex but in the limbic system of the brain" (1974, p. 348).

Discussion

It appears that basic human emotional experience is an emergent property of the functioning of mechanisms that originally served to regulate the emission of species-specific behaviors which were elicited directly by releasing stimuli in survival-related situations. The functional system which evolved in humans decouples stimulus and response. Thus, in humans, it is the emotional experience evoked by a stimulus--rather than the stimulus itself--that is the primary motivating factor (reinforcer) which ultimately determines behavior. Further, this emotional experience might be most properly considered to be a part of the experiencing person's environment, since that experience is involuntary and has the power to condition the person's response. These processes appear to have their functional impact in the left hemisphere, where the formulation of behavioral responses occurs.

The physiological mechanisms which motivate adaptive behavior in humans are centered on the amygdala which integrates information from the internal and external environments in order to attach emotional significance to stimuli. This structure is involved in the

encoding and retrieval of this information in memory and forwards its signals to the prefrontal lobes where they are experienced as subjective emotions. The prefrontal lobes appear to utilize these signals in the process of forming intentions to direct adaptive behavior. This amygdala-prefrontal pathway appears to be the substrate of anxiety and depression. When the amygdala-frontal connection is severed surgically, or uncoupled pharmacologically, the neocortex experiences euphoria, but fails to behave in an adaptive manner.

Memory Functions

It is evident that the functional brain systems which form the infrastructure of personality include separate cognitive, affective and arousal components. It appears that these subsystems evolved to take full advantage of a form of learning which utilizes reinforcement and emotional experience in determining behavior. The product of any learning experience is memory. The importance of memories (or "associations") in the organization of cognitive operations is obvious and most, if not all, arousal and affective processes must depend on the ability to discriminate personally relevant stimuli. Clearly, memory is fundamental to all aspects of personality function, but the material substrate of memory remains a complete mystery (e.g., Lashley, 1950; Luria, 1973a); our concepts regarding it are, of necessity, only abstract descriptions. Before reviewing the physiological organization of memory systems it will be necessary to define and delimit, as far as possible, those abstract

concepts of memory phenomena that are pertinent to the interests of the applied psychologist.

Experimental psychologists have traditionally approached the study of memory by subdividing it into registration, retention, and recall, attempting to isolate and measure these aspects and the variables which affect them. Rapaport (1961) criticized this methodology as artificial, insisting that these functions are inextricably related and that such experiments merely demonstrate how memory can function under given laboratory conditions. Working from a psychoanalytic perspective, Rapaport preferred to treat memory as an aspect of cognition. He argued that "actual memory phenomena are encountered only in the context of thought processes; at best the classical memory experiments could ignore this fact and make us ignore it, but they could not produce memory phenomena outside this context" (Rapaport, 1961, p. 6). He acknowledged the difficulties in determining the relation of indistinct entities such as emotion and memory and attempted to clarify the psychoanalytic viewpoint by suggesting that "memory is a motivated behavior phenomenon and . . . emotions are motivating factors" (Rapaport, 1961, p. 8). This statement, however, appears to beg the question; if memories are activated by emotions, then what initiates arousal and affective processes?

The interaction of cognition, affect and memory in the etiology and cure of psychopathology were central themes in the work, published in 1893 by Josef Breuer and Sigmund Freud, which gave psychoanalysis its start. The emphasis on the significance of

memory phenomena in psychoanalytic literature (e.g., slips of the tongue, forgetting, false remembering, repression) can be traced to this seminal paper in which the authors concluded that "hysterics suffer mainly from reminiscences." In this work, Breuer and Freud made a crucial distinction regarding the memory processes operating in psychoneurosis which may have sowed the seed from which the notion of unconscious causation of psychological phenomena germinated:

. . . the causal relation between the determining psychical trauma [an experience which calls up distressing affects such as those of fright, anxiety, shame or physical pain] and the hysterical phenomenon is not of a kind implying that the trauma merely acts like an agent provocateur in releasing the symptom, which thereafter leads an independent existence. We must presume rather that the psychical trauma--or more precisely the memory of the trauma--acts like a foreign body which long after its entry must continue to be regarded as an agent that is still at work. (Breuer & Freud, 1974, p. 355)

The authors became aware of this "highly remarkable phenomenon" and its relation to affective processes in the course of their experimental treatment of hysterical conversion symptoms:

[we found] that each individual hysterical symptom immediately and permanently disappeared when we had succeeded in bringing clearly to light the memory of the event by which it was provoked and in arousing its accompanying affect, and when the patient had described that event in the greatest possible detail and had put the affect into words. Recollection without affect almost invariably produces no result. (Breuer & Freud, 1974, p. 355)

Hillix and Marx (1974) have suggested that "it was necessary for Freud to invent the psychic apparatus and much of his psychoanalytic theory just to account for what he and Breuer had already observed" (p. 352). It is to be hoped that recent evidence will make a more parsimonious accounting possible.

The implicitly verbal form of memory referred to by Rapaport seems to be qualitatively different from the "foreign body" which Breuer and Freud assumed to be the culprit in hysterical neurosis. They referred to the latter type of memory by the less formal term "idea" and indicated that symptom removal depends on the transformation of this "idea" into a more formal thought process so that its associated affect can be abreacted:

[the therapeutic procedure] brings to an end the operative force of the idea which was not abreacted in the first instance, by allowing its strangulated affect to find a way out through speech; and it subjects it to associative correction by introducing it into normal consciousness. (p. 356).

This special type of memory would seem to merit a more detailed description. It is evident that we are concerned here with a subset of memories which have significance for the individual. By definition, these are memories that are associated with reinforcement and/or emotional experience. They are experiential (nonverbal) and may be isolated from consciousness. It may be noted that this subset of memories will define the relationship between the individual and his or her environment and might be the organism's most important survival resource. A concept from social learning theory seems to encompass this type of memory comfortably and provides a more operational definition.

Julian Rotter (1966) theorized that "a reinforcement acts to strengthen an expectancy that a particular behavior will be followed by that reinforcement in the future" (p. 2). Further, "when an organism perceives two situations as similar, then his expectations

for a particular kind of reinforcement, or class of reinforcements, will generalize from one situation to another" (Rotter, 1975, p. 57). Rotter distinguished two types of "generalized expectancies" (GE). The first has to do with the nature of the reinforcement: expectations for a particular kind of reinforcement in a given situation. The second type deals with other properties of situational stimuli and has to do with the perception of control that one can exercise to change or maintain the situation: the kind of behavior that is likely to produce or terminate reinforcement. The first type is designated with a subscript r for reinforcement (GE_r). The second type is designated a problem-solving generalized expectancy (GE_{ps}). Striking insights into the nature and mechanics of this sort of experiential memory were afforded by Penfield's observations of certain psychical phenomena elicited by direct electrical stimulation of the conscious brain (see Mullan & Penfield, 1959).

Wilder Penfield's data were collected from patients undergoing radical brain surgery, with local anesthesia, for the relief of intractable epilepsy. His observations consist of spontaneous reports from these patients following applications of a mild electric current to the exposed cortex from the tip of a unipolar electrode. The responses to such stimulation which are of interest here fall into three categories:

1. The emergence in consciousness of vivid and coherent experiential hallucinations which appeared to be recollections of (or abstractions from) the subject's past experiences.
2. Changes in a patient's subjective experience of his or her relationship with the immediate environment.

3. "Illusory" emotional experiences.

Based on his analysis of the data, Penfield (1975) postulated the existence of two related brain systems: a "mechanism of recall," and a "mechanism of interpretation." The latter involved the temporal cortex (exclusive of the speech areas) and was referred to by Penfield as the "nonverbal concept mechanism." Penfield compared its function with nonverbal concepts to the operation of the speech cortex with verbal concepts.

Somehow [this mechanism] seems to analyze the components of sensation, compares them with previous experience, and by that analysis and comparison, transmits into consciousness their present and immediate significance . . . [an emotional response] is a signal that rises into consciousness as a result of an interpretation of what the present situation may bring the subject in the immediate future.. (Mullan & Penfield, 1959, p. 283)

It appears that the cognitive products of these mechanisms fit the criteria for generalized expectations. Penfield's evidence assists in understanding the different types of memory referred to by Rapaport and by Breuer and Freud and indicates the neural substrate of these processes. (Penfield's data and conclusions will be reviewed and evaluated in detail presently.)

It has been assumed here that at the base of personality there are mechanisms whereby cognitive operations and affective processes are appropriately activated by significant memories. The present task is to describe neurological evidence which accounts for the memory phenomena reviewed above in terms that fit the criteria for "functional systems" as defined by Luria, and satisfy the evolutionary imperatives outlined at the beginning of this chapter.

The neuropathological correlates of human amnesia syndromes and data from related animal studies will be reviewed. It will be hypothesized that human beings possess two autonomous, lateralized memory systems, centered on the hippocampi, each of which is intimately associated with its own emotional and cortical activating system.

Human Amnesia Syndromes

A number of terms are used to describe different aspects of memory function and dysfunction. Immediate memory, usually measured by digit span, probably reflects the ability to hold information in the primary or secondary sensory cortex as long as voluntary attention (directed by the nonspecific thalamic nuclei) is focused upon it (Smithies, 1966). The terms short-term ("recent") and long-term ("remote") memory indicate recollection over increasingly greater periods of time, but both are almost certainly subserved by the same physiological processes (Brierley, 1977). The term retrograde amnesia refers to a period of time before an accident or illness for which the patient's ability to recall is diminished or lost. Anterograde amnesia is an inability to retain in memory events that occur after such an injury or illness.

The combination of a severe retrograde amnesia and a debilitating anterograde amnesia is the hallmark of the Wernicke-Korsakoff syndrome, the most common form of memory disease. This illness is most frequently seen as a result of brain lesions brought on by dietary (thiamine) deficiencies in chronic alcoholics, although the lesions and illness may be produced by a number of toxic or disease processes (see the excellent review by Brierley, 1977). This illness

was described independently in the 1880s by Karl Wernicke (whose work with aphasia was reviewed earlier) and S. S. Korsakoff, a Russian psychiatrist. Wernicke focused on the acute stage of the illness during which the patient is usually depressed, fearful and anxious; often paranoid; and always severely confused and disoriented (Wernicke's encephalopathy). Patients who survive this acute stage become stabilized in the phase known as Korsakoff's psychosis. This chronic state is characterized by severe memory disorders and profound changes in the patients personality, motivation, and affect.

Against a background of retained intellectual skills and intact remote memory, the victim of Korsakoff's psychosis suffers a retro-grade amnesia for periods of up to several years before the onset of the illness, and an almost total inability to recall any new information once his or her attention is distracted from it. Consequently, these patients live virtually in the immediate present and are always disoriented as to time, place and situation. These patients are, at best, only vaguely aware of their inability to learn new material. They often produce confabulations to cover gaps in their recollection and fuse or combine ("reduplicate") experiences from different periods in their lives (Gardner, 1975). In both cases they believe that their statements reflect reality. In most cases the patient's affect is blunted, although some patients have exhibited chronic euphoria (e.g., Remy, 1942). They show reduced spontaneity and initiative and a "lack of desire for alcohol, sex, and other traditional reinforcers" (Gardner, 1975, p.1188).

(Such indifference to alcohol is especially interesting in light of the fact that the brain damage in most of these patients was caused by years of sustained, heavy drinking.)

Post-mortem examination of the brains of persons who suffered from Wernicke-Korsakoff disease reveals lesions of certain anatomical structures in the limbic system associated with the well-known circuit of Papez. Such damage almost invariably includes, and may be confined to, injury to the mammillary bodies, the relay for hippocampal output on its way to the anterior thalamic nuclei (Brierly, 1977).

A pure form of this memory disorder was the unfortunate consequence of bilateral removal of the hippocampi in humans. In the 1950s Scoville performed a series of experimental operations designed to relieve the symptoms of chronic schizophrenia without the undesirable side-effects of a complete frontal lobotomy. The surgical procedure involved the resection of the medial surface of the temporal lobes from 5.0 to 8.0 cm posterior to the tip of the lobe combined in some cases with orbital undercutting. Thirty severely deteriorated schizophrenics had undergone the operation, with slight improvement in their conditions, when a purely temporal resection was performed on a nonpsychotic epileptic patient whose seizures were unresponsive to medication. When this patient, "case H. M.," recovered from the operation it became apparent that he had developed a severe amnesic disorder which resembled Korsakoff's psychosis and which persisted at 14 years (Milner, Corkin & Teuber, 1969). Scoville and Milner subsequently examined eight of the psychotic patients

who had undergone the operation and who were able to participate in formal testing. They discovered "some generalized memory disturbance in all patients with removals extending far enough posteriorly to damage portions of the hippocampus and hippocampal gyrus (Milner, 1958, p. 112). The degree of memory impairment was more or less proportional to the amount of these structures removed. Bilateral resection of the uncus and amygdaloid nucleus alone did not result in amnesia (Brierly, 1977), nor did removal of the gyri of the outer aspects of the temporal lobes (Bailey, 1946). It has been concluded, therefore, that "the structures necessary for normal memorizing are the hippocampal formations within the temporal lobes, the mammillary bodies and, possibly, certain thalamic nuclei within the diencephalon" (Brierley, 1977, p. 221); that is, the hippocampi, their output pathways and related projection sites.

There has been, as yet, no definitive explanation of either the nature of the amnesic deficit described above or of its underlying mechanisms. The fact that remote memory seems to be intact in these patients has led many to believe the the hippocampal-diencephalic structures are not involved in the process of recall, although Brierley (1977) pointed out that such a conclusion is unjustified in the absence of adequate pre-post evaluation of this function. Milner (1966, ch. 5) attempted to account for the pairing of a period of retrograde amnesia with an inability to learn new material by hypothesizing that the establishment of a permanent memory trace requires an extended period of "consolidation," which is somehow disrupted in this syndrome. In Milner's view the deficit

represents a failure to transfer sensory impressions into long-term store. The adequacy of the consolidation hypothesis is called into question, however, by demonstrations that amnesic patients are in fact able to recall new information under certain conditions. The most convincing evidence comes from experiments using the technique of "cued recall" in which a subject is given partial information about a stimulus (e.g., a previously presented word or picture) and asked to identify the whole item. Under these circumstances the performance of amnesic subjects was not significantly different from that of controls (Weiskrantz & Warrington, 1970). This suggested to the authors that the amnesic deficit involved problems with mechanisms of retrieval rather than those of acquisition or retention.

Weiskrantz (1979) reviewed a number of experimental paradigms in which normal learning has been demonstrated in amnesic subjects and underscored the fact that, in each case, the patients themselves persistently failed to acknowledge the fact that their performance was based on specific past experience (or that they had been confronted with the task before). Thus, amnesia victims do not have access to their memories on a conscious level, nor is such awareness necessary for that memory to be demonstrated objectively. Weiskrantz pointed out that this "striking dissociation between the subjects' commentaries and their objective performance . . . suggests a dissociation between levels of processing rather than a failure on any particular level" (p. 385).

Levels of processing in memory are the subject of a theory (summarized by Gaffen, 1972) which is based on arguments by Talland (1965) and supported by experimental evidence (Peterson, 1967; Kintsch, 1970). Briefly, the theory postulates that the process of recall consists of two separate and autonomous stages: retrieval (or search) and recognition. The retrieval process "proceeds at several levels . . . each being terminated by an implicit act of recognition" (Talland, 1965, p. 304). The recognition stage is based on a record from which the past cannot be read directly, but which can assign a particular response in a particular context a value of "familiarity--unfamiliarity" (the correct response being the most familiar in that context). Thus "[in the retrieval stage] various responses are generated (but not emitted); when finally the correct response is generated, it is recognized as such by the recognition stage, and is then emitted" (Gaffen, 1972, p. 328). The theory postulates that amnesic subjects (animal and human) lack the faculty of discriminating familiarity. This basic deficit is manifested in the premature termination of search cycles, resulting in an incorrect match. These formulations are not inconsistent with those of Butters and Cermack (1974), who concluded from their experiments that increased sensitivity to proactive interference, subsequent to inappropriate encoding of information, was the critical factor underlying the amnesic disorder. Finally, it is interesting to note that modern theories regarding amnesia seem to have arrived at the point at which they began: Korsakoff (1889), in keeping with the associationist doctrine of his time, believed

that his patients were deficient in making associations among new ideas and in connecting past and present experience.

The suggestion of bilevel processes in memory noted above are particularly interesting given that language and conscious awareness have been associated with temporal lobe structures of the left hemisphere, and Penfield's (1975) report that electrically induced "illusions of recognition" were elicited only by stimulation of temporal structures of the right hemisphere.

Memory and the Neocortex

As noted earlier, Penfield's experiments with electrical stimulation of the cortex in conscious patients led him to postulate the existence of two separate memory systems: a "mechanism of recall" and a "mechanism of interpretation." The existence of the former was suggested by the fact that, following stimulations of the exposed cortex, some of his patients reported vivid auditory and/or visual experiences ("flashbacks"); it seemed to the patients as if they were reliving prior experiences in their lives, although they retained their awareness of the operating room environment. Since many of these sensory sequences were trivial, yet perceived as familiar, Penfield concluded that his electrode was tapping a "continuous record of conscious experience." Although widespread areas of the cortex were exposed and explored, these "experiential responses come only from the temporal lobe, never from any other part of the brain" (Penfield, 1975, p. 31).

Niesser (1967) presented persuasive arguments refuting Penfield's claim that "nothing is lost . . . the brain of every man contains an

unchanging ganglionic record of subjective experience" (Penfield, 1954, p. 67). Niesser suggested that "most of the cases described by Penfield seem more like generic and repeated categories of events rather than specific instances" (p. 168). (It will be noted that Niesser's formulation is congruent with the notion of a "generalized expectation," as defined earlier.)

Penfield's second mechanism was suggested by another category of electrically induced phenomena which consisted of the "misrepresentation or altered interpretation of present experience" (Mullan & Penfield, 1959, p. 269). Prominent among these were "illusions of recognition" during which "present experience seemed familiar, strange, altered, or unreal" (p. 270). These "illusions of comparative interpretation" were associated with stimulation of the temporal cortex in the hemisphere that was minor for handedness and speech. The authors believed that "in normal life, these are signals that rise into consciousness, signals that depend on subconscious comparison of past experience with the present" (p. 283).

In 1951 Penfield proposed that portions of the temporal lobes be called "memory cortex" in the belief that his electrode had activated a neuronal record which was stored there. He was obliged to revise this theory in 1958 because of a new understanding of the physiology of electrical brain stimulation. When an electrode passes a current into the cerebral cortex, the current completely disrupts the patient's normal use of that gray matter (e.g., stimulation of the speech areas produces momentary aphasia). Therefore, any positive responses are produced by axon-conduction and the functional

activation of a distant, secondary ganglionic station (Penfield, 1975, ch. 7). In his later formulations then, Penfield referred to those temporal structures as the "interpretive cortex" and postulated that his electrode had activated a final common pathway to a secondary center which in turn produced the illusions of comparative interpretation. Since the temporal lobe forms the principal source of input into the hippocampus (which was known to be related to memory), Penfield assumed that this was the secondary center in question. He suggested that

The hippocampi seem to store keys-of-access to the record of the stream of consciousness. With the interpretive cortex, they make possible the scanning and the recall of experiential memory. (Penfield, 1975, p. 36)

Penfield's finding that illusions of familiarity were associated with activity of the temporal lobe in the right hemisphere is complemented by Kimura's (1963) evidence that the right temporal lobe appears to be more involved in the analysis of unfamiliar stimuli. Kimura presented familiar and unfamiliar visual stimuli to the right and left visual fields of patients with lesions of the right or the left temporal lobe. The right temporal group was impaired in the perception of the unfamiliar stimuli but not the familiar. Kimura interpreted her results in terms of the verbal identifiability of a stimulus:

It seems clear that a frequent (though not a necessary) concomitant of familiarity in a perceptual sense is the possibility of verbal identification. Where increased familiarity with a stimulus object, or class of objects, is associated with the repeated naming of the object, the ability instantly to attach a name to it represents an important step in the development of a concept. It

seems probable that in such cases a large part of the increase in permanent neural representation which is assumed to correlate with familiarity will take place in the language centers, that is, in the dominant hemisphere. (Kimura, 1963, p. 269)

Thus, unfamiliar stimuli, which are not represented in verbal memory by a permanent neural model (e.g., a name or concept) are more likely to be processed by the right hemisphere, which Kimura suggests is more important than the left in the establishment of such "cell assemblies." Since all of the material in the memory store are initially unfamiliar it follows that many, if not all, verbal concepts (in the left hemisphere) might be based on neural models, or gestalten, which were assembled (and are stored) in the right hemisphere. Such an hypothesis is supported by evidence from split-brain studies that the right hemisphere is far superior to the left in the discrimination of part-whole relationships (Nebes, 1974).

The appearance of material-specific amnesia syndromes following unilateral temporal lobectomies suggests that the isolation of language in the left hemisphere extends to verbal learning also, and is thus virtually complete. Milner (1971) reports that:

A comparison of left and right anterior temporal lobectomy in epileptic patients has revealed certain specific memory defects that vary with the side of the lesion. These material-specific disorders are to be distinguished from the global amnesia that follows bilateral damage in the hippocampal zone (Milner, 1958). Thus, left temporal lobectomy, in the dominant hemisphere for speech, selectively impairs the learning and retention of verbal material (Meyer & Yates, 1955; Milner, 1958). . . . Conversely, removal of the right, nondominant temporal lobe leaves verbal memory intact but impairs the recognition and recall of visual and auditory patterns

that do not lend themselves easily to verbal encoding. . . . Thus within the sphere of learning and memory there is a double dissociation between the effects of these two lesions." (Milner, 1971, p. 274)

Butters and Cermack (1974) focused on the specifically verbal aspects of the amnesic disorder in Korsakoff patients and noted that, during learning tasks, these patients did not react to changes in semantic categories on successive lists. They concluded that the amnesic deficit was due to the patient's

inability to encode verbal information along semantic or meaning dimensions. . . . Korsakoff patients do not spontaneously employ semantic encoding strategies, but rely on basic acoustic and associative categorizations. If the Korsakoff patient is instructed to encode semantically, he will do so, but in an impaired manner. (pp. 74-75)

Butters and Cermack assumed that the Korsakoff patients' deficient utilization of "meaning" in learning tasks was a specifically verbal (i.e., left hemisphere) phenomenon. However, Gazzaniga and his colleagues produced evidence which suggests that the right hemisphere may play an important role in imparting "meaning" to verbal memory processes. These authors tested patients with partial or complete section of the cerebral commissures for recall of two lists of paired-associate nouns. On presentation of the second list each patient was instructed to "form a 'picture in his mind' of the two items interacting in some unusual or amusing way" (Gazzaniga, Risse, Springer, Clark & Wilson, 1975, p. 12). Patients with partial sectioning of the cerebral commissures showed marked improvement with the imagery instructions but none was seen where there was complete section of the hemispheric interconnections.

Discussion

The evidence reviewed thus far suggests that the central problem in the amnesia syndromes involves mechanisms which normally facilitate access to stored memory traces. The problem might occur at the point of encoding and deposition, or retrieval, or both. The hippocampus appears to be critical to these coding and decoding operations; this structure may normally provide the memory "cues" which must be externally administered in its absence.

The evidence is supportive of Niesser's (1967) proposal that (rather than tapping a "continuous memory strip") "Penfield's electrode may have touched on the mechanisms of perceptual synthesis" (p. 169). There can be little doubt that Penfield's "final common pathways" in the temporal lobes are related to hippocampal afferents. However, it is now clear that the hippocampus cannot be the only secondary ganglionic station which must be activated before a signal indicating familiarity, originating in the right hemisphere, can "rise into consciousness." Studies of split-brain patients have shown conclusively that the ability to give a verbal account of events occurring in the right hemisphere is dependent on the integrity of the cerebral commissures (e.g., Sperry, 1968). The general layout of the commissures is such that a specific area in one hemisphere is connected via commissural fibers to the homologous area in the contralateral hemisphere. The temporal lobes have their own private interconnection in the anterior commissure, which also connects the two amygdalae (Gray, 1977). Studies of patients with only partial sectioning of these commissures have indicated

that highly processed information might be even more "transferrable" than elementary sensory information and may be able to utilize any commissural pathway that is available (Gazzaniga et al., 1975).

It appears that there are two separate and autonomous memory systems in the brain which are specialized as to their function: a verbal system, lateralized in the left hemisphere, and a nonverbal (experiential) system lateralized in the right. The evidence suggests that memory functions might be conceptualized as having both vertical and lateral dimensions: the scanning (or search) within each system may involve a temporal-hippocampal interaction and the phenomenon of recognition may be a function of right-left temporal lobe interaction.

A voluntarily initiated search of memory would, most certainly, begin in the left-hemisphere system, but an environmental stimulus might activate an initial nonverbal (right-hemisphere) scan and analysis. In either case, the result of these processes would seem to be the emergence in conscious awareness of a signal indicating the "familiarity" (or "strangeness") of the stimulus and, finally, the facilitation of generalized expectations and verbal associations related to that stimulus. The implications of such a formulation for the understanding of psychopathological processes and the practice of psychotherapy will be discussed in later sections, following an evaluation of the limbic system's role in experiential and emotional memory.

The Limbic System, RAS, and Memory

Little distinction is made in the human amnesia literature between the verbal, experiential, and emotional aspects of memory. The verbal manifestations of the disorder are the most obvious, the most amenable to description and testing, and so have become the primary focus of scientific attention. Although it is seldom emphasized, most case studies of amnesia victims relate anecdotal evidence of emotional dysfunction (e.g., blunted or flattened affect; euphoria). There are also more or less vague, but consistent, references to what might be termed disturbances of tonic arousal ("decreased spontaneity," "lack of initiative," "indifference," "passivity"). These emotional and arousal difficulties appear to be associated with systems centered on the amygdala and RAS, respectively. Both of these will be described below following a consideration of the nonverbal, predominantly unconscious mechanisms of experiential memory.

Before an organism can respond to a stimulus on any level (emotional, verbal, or behavioral) its meaning must be ascertained. At the most elementary level the organism's survival depends on its ability to make appropriate decisions about whether to invest neural energy in attending to and further analyzing a particular stimulus (orienting) or to ignore it (habituation). Such a decision demands a judgement as to the apparent novelty, possible significance, or lack of these qualities in the stimulus configuration, a process which requires access to a patterned memory trace or "neural model" (Sokolov, 1963). Such a process must begin with sensory

input and end with afferents which are capable of modulating the activity of the brainstem RAS.

A determination of novelty or significance might be made at the level of the secondary sensory association cortices where raw receptor impulses are converted into functional (i.e., "meaningful") information, although such duplication of effort in all the modalities would be cumbersome and inefficient. Further, the relative significance of a stimulus may depend on the internal state of the organism (e.g., satiation, the presence or absence of certain hormones, etc.). The fact that information related to this added consideration is most readily available in subcortical structures is another argument favoring a centralized location for the mechanisms involved with the decision to orient or habituate. The hippocampus meets all of the criteria specified above.

Luria concluded that "many neurons in the hippocampus and connected nuclei do not respond to modality-specific stimuli of any sort, but serve to compare present stimuli with traces of past experience; they react to every change in the stimulus and thus play to some extent the role both of 'attention neurons' and of 'memory neurons'" (1973a, p. 289). According to Luria the hippocampus provides for the "elimination of responses to irrelevant stimuli and enables the organism to behave in a strictly selective manner" (1973a, pp. 271-272). It appears that the hippocampus accomplishes this complex task by coordinating the activities of the cortical and subcortical mechanisms which are directly involved in the processes of attention, memory and learning.

Early investigators were puzzled by the fact that cortical activation (EEG desynchronization) was accompanied by synchronous slow-wave activity (4-8 Hz theta rhythms) in the hippocampus (e.g., Green & Arduini, 1954). The most constant behavioral correlation of hippocampal theta activity in animals of different species is orienting towards, and attending to, stimuli in the environment (Isaacson, 1974). Cortical activation, such as that seen in the orienting response, is accomplished by the brainstem RAS in conjunction with the nonspecific thalamic nuclei. The hippocampus appears to regulate the process of involuntary attention by performing switching functions through a mutually inhibitory relationship with the reticular formation (Smithies, 1966). The Soviet neuropsychologist Vinogradova provided important insights into the mechanics of this process.

By observing unit activity with microelectrodes Vinogradova (1970) determined that all of the neurons in the hippocampus monitor incoming stimuli, habituating to repetition and dishabituating to any change in the stimulus configuration. Such responsiveness requires constant matching of the stimulus with a related neuronal model (Sokolov, 1963). That these models exist in the cortex, and not in the hippocampus itself, is established by evidence that the quality of sensory information is almost completely erased in hippocampal neurons (Gloor, 1961).

Vinogradova distinguished two types of neurons in the hippocampus: A-neurons (30-40%) which are activated by a stimulus and I-neurons (60%) which are inhibited. She went on to propose a mechanism whereby the hippocampus is able to modulate the processes of attention and learning:

The hippocampus exerts a tonic inhibitory influence upon the reticular formation, blocking activatory processes through the tonic discharge of its I-neurons when novelty is absent and registration [a change in the neuronal model] is not needed. But when a stimulus which is not registered in the memory system appears, this inhibitory control is blocked (I-neurons become silent), arousal occurs, and the process of registration starts. (1970, p. 114)

Vinogradova's hypothesis is supported by observations of electrical activity in the brains of animals in classical conditioning paradigms. Theta rhythms (associated with activity of Vinogradova's A-neurons) are found in the early stages of learning but disappear when the response has become well established (Isaacson, 1974). During conditioning the time course of the theta rhythm and the orienting response are matched. As the latter is replaced by the stabilized conditioned response, theta dies out (I-neurons become active again) and the hippocampus resumes its inhibitory control over the RAS, thus ending the orienting response and thereby allowing the fully developed conditioned response to materialize (Smithies, 1966, p. 90).

The hippocampal-cortical interaction was apparent in an analysis of the characteristics of hippocampal theta rhythms in situations requiring different types of cortical information processing. Bremner (1970) investigated the effects of orienting, simple conditioning, discrimination, and discrimination reversal tasks on various parameters of the theta rhythm using the habituated organism (rat and man) as a baseline. He found that theta power (amount of energy) increased in the presence of stimuli which elicited orienting and arousal and decreased in the interval preceding a response in the conditioning situation; the range of energy distribution

around the peak frequency narrowed during discrimination; and the location of the peak shifted in discrimination reversal procedures.

In summary, the hippocampus appears to be able to monitor incoming stimuli and match them against (cortical) neuronal models which represent the past experience of the organism with related stimuli. In addition to facilitating appropriate access to these memory traces hippocampal activities have been directly associated with the triggering of cortical processes which permit further analysis of a stimulus, emotional and behavioral responses as warranted, and/or alterations in the neuronal model itself (i.e., learning).

Papez Circuit and Memory

The hippocampus forms part of a continuous pathway within the limbic system which Papez (1937) believed to be the substrate of emotion. Papez was aware that destruction or stimulation of limbic structures produced major alterations in emotional behavior and believed that emotional expression depended on the integrative action of the hypothalamus. He was also convinced that subjective emotional experience required the participation of the cerebral cortex. Papez outlined an anatomical circuit through which he thought emotion might arise in either of those two centers. Thus.

Incitations of cortical origin would first pass to the hippocampal formation and then down by way of the fornix to the mammillary body. From this they would pass upward through the mamillothalamic tract . . . to the anterior nuclei of the thalamus and thence by the medial thalamocortical radiation (in the cingulum) to the cortex of the gyrus cinguli . . . Radiations of the emotive process from the gyrus cinguli to other regions in the cerebral cortex

would add emotional coloring to psychic processes occurring elsewhere. (Papez, 1937, pp. 304-306)

Papez believed that sensory input to the system originated in the thalamus and was communicated via the subthalamus to the hypothalamus. The circuit is completed with the connection of the cingulate gyrus to the hippocampus by way of the cingulum bundle.

It is now known that other limbic structures are more actively involved in the specifically emotional processes. However, Papez's anatomical concepts might be rehabilitated if their context were changed from emotion to memory. Input to the hippocampal circuits would be seen as processed sensory information and its output as memory indexing information capable of "cueing" associations and generalized expectations related to the input stimulus. It remains to place the role of the hippocampus in the context of the functional system it subserves and to examine the other components of that system.

Fornix. Hippocampal output makes its way via direct and indirect pathways to the thalamus (anterior, dorsomedial, and intralaminar nuclei), the hypothalamus, and the midbrain reticular formation. Its main efferent fiber system, the fornix, is composed of axons from pyramidal cells in the body of the hippocampus. These fibers converge in the fimbria, traveling backwards within the temporal lobe, and then arch forward under the corpus callosum as the crura (posterior pillars) of the fornix. Here a number of fibers cross to the other side, forming the hippocampal commissure. The two crura then join to form the body of the fornix which

continues to arch forward, following the course of the lateral ventricle to the rostral edge of the thalamus. Here the bundles separate again to form the anterior columns of the fornix which curve downward in front of the intraventricular foramen and above the anterior commissure (AC). Approximately half of the fibers descend behind the AC as the postcommissural fornix; the other half, in a less compact bundle, pass in front of the AC as the precommissural fornix. Postcommissural fibers pass through the hypothalamus to the mammillary bodies, giving off fibers to the thalamus on their way. Some of the precommissural fibers distribute to the septal area and others join with septal fibers and continue into the same areas as the postcommissural fornix. Approximately one-third of the fornix fibers reach the mammillary bodies (Daitz, 1953); the anterior nuclei of the thalamus receive as many direct fibers from the fornix as they do from the mamillothalamic tract (Truax & Carpenter, 1969, ch. 21).

Liss (1968), working with the rat, found that hippocampal and fornix lesions had analogous effects on learning and behavior in passive and active-avoidance tasks. In the monkey, fornix lesions led to impaired learning of a spatial reversal task that was "functionally similar" to the deficit seen after hippocampal removal (Mahut, 1972; Mahut & Zola, 1973). Gaffen (1972) reported a series of six experiments in which rats with fornix lesions were shown to have a defect in "recognition memory" that the author argued was equivalent to anterograde amnesia in humans. In Russel's (1971) survey of brain wound cases, the eight patients who showed

a Korsakoff-type of memory disorder were thought to have had their fornices damaged by metal fragments. Four of the five cases with typical amnesic syndromes in Jarho's (1973) study of brain-injured war veterans were considered to have bilateral interruption of the fornix or mammillothalamic tract.

Sweet, Talland, and Ervin (1959) reported the case of a woman in whom the anterior columns of the fornix were sectioned to facilitate the removal of a colloid cyst of the third ventricle. This patient showed a rapid recovery of old skills, but developed a "severe loss of memory for recent events [which persisted at two years] . . . a retrograde amnesia of at least several weeks and a subjective complaint of amnesia for specific events of four or five years past" (p. 76), coupled with intact remote memory. In the discussion following the presentation of this patient, Brenda Milner reported on a similar case operated on by Welsh in 1954. This patient showed a gross initial memory disorder but, at one year, was able (with effort) to effect some compensation for his defect: "Whenever he deliberately sought associative links he was able to improve his performance considerable" (Sweet. et al., 1959, p. 79). Milner concluded that.

I think that one can only account for the paradoxical diversity of data from the fornix cases, as contrasted with the consistent and severe memory loss in the hippocampal cases (and maybe in the mammillary body cases also), by supposing that you are only interfering with a part of the system by fornix section. Thus, you are most apt to see a temporary disruption of disturbance of memory with minimal residual loss. (p. 79)

Data on the fornix is relatively scarce, and there have been reports of negative findings. In his influential review, Brierly (1977) took a very conservative stance on this subject:

The most discrete link between the hippocampal and diencephalic regions is the fornix. It is surprising, therefore, that with the exception of the case reported by Sweet, Talland and Ervin (1959), bilateral division of the fornix (usually in the region of the intraventricular foramen) has not resulted in a disorder of memorizing (Dott, 1938; Cairnes & Mosberg, 1951; Garcia-Bengochea and his colleagues, 1954). This finding suggests that the two groups of structures linked by the fornix cannot be regarded as a unitary system subserving the process of memorizing, at least until major interconnections other than the fornix have been identified. (pp. 221-222)

Other interconnections are available. Smithies (1966) describes a "massive direct hippocampal-hypothalamic pathway" that runs diffusely through the subthalamus and which he suggests might be "quite able to carry on hippocampal and limbic circuit function in the absence of [the fornix]" (p. 122). A second look at the reports cited by Brierley, however, allows the possibility that his conclusions are premature.

Sweet et al. (1959) emphasized that their patient's "conversations, social amenities, and general demeanor gave little evidence of [her] severe deficits unless they were specifically looked for" (p. 76). They also noted that she lacked spontaneity, made little effort to converse, and was apparently indifferent to her deficits (cf. Korsakoff's syndrome). The very brief report of Bengochea, De la Torre, Esquivel, Vieta and Fernandez (1954), after a "short follow-up" of their patients (whose fornices were severed in an experimental operation to relieve intractable epilepsy) did not

mention any attempt at quantification of behavior. They simply stated that "so far, in none of the 12 surviving cases there has been [sic] any unfavorable neurological or psychiatric sequela" (p. 177). It seems possible that these authors may have missed subtle symptoms in their apparently superficial evaluation.

Wilder Penfield (quoted in Sweet et al, 1959) underscored the fact that "patients who have [bilateral hippocampal lesions] do not forget their skills. Two of them were able to carry out most complicated skills learner previous--glove cutting and engineering drawing" (p. 81). Unfortunately, the only behavioral measure reported by Cairnes and Mosberg (1951) involved a return to work. These authors noted that some of their patients (who had incurred fornix damage in the course of surgery to remove colloid cysts of the third ventricle) showed initial confusion, loss of memorizing, and amnesia for the period surrounding the operation, but: "after operation all [but one of their nine surviving cases] returned to work, and . . . showed no disturbance of emotion or intelligence" (p. 564). Thus

Four of the five young women . . . are doing normal housework; three have borne children. The other young woman is in regular work as a clerk, and is free from complaints. . . . Two older women . . . are also doing their housework [although one has a 'slight impairment of memory']. . . . Of the two men, one is working regularly as a policeman. (p. 568)

The extent of the lesions in these patients is unclear. The authors report only that "each had . . . partial or complete division of the anterior columns of the fornix" (p. 564). (It seems possible that these surgical fornicotomies spared the precommissural fornix.)

It should be noted that a colloid cyst of the third ventricle tends to produce confusion, dulling of attention and memory, and sometimes a progressive dementia prior to its surgical removal. These factors would make a pre-post evaluation of memory function very difficult. Still, the scantiness of the reported data in the studies reviewed above is unfortunate. It is evident that injuries to different parts of this system result in different expressions of the disorder. It is reasonable to conclude, however, that damage to the fornix has adverse effects on memory function which vary as to the quality and degree, and may leave a greater possibility of recovery of function.

Mammillary bodies and mamillothalamic tract. The mammillary bodies are a collection of nuclei at the posterior boundary of the hypothalamus. They form a major relay station for hippocampal output on its way to the thalamus (via the mamillothalamic tract) and to the midbrain reticular formation (by way of the mamillo-tegmental tract).

In humans, damage which is apparently limited to the mammillary bodies has resulted in the full Korsakoff amnesic syndrome (Remy; 1942; Delay & Brion, 1951; Gruner, 1956; Symonds, 1966), although Victor (1964) suggested that additional damage to the thalamus was necessary to produce the disorder. In the rat, lesions of the mammillary bodies or of the mamillothalamic tract impaired the ability to perform a spatial discrimination in a T-maze in order to avoid footshocks (Thompson, Langer & Rich, 1964). Kriekhaus (1962, 1964) found that complete or partial destruction of the

mammillothalamic tract in the cat reduced the retention of a two-way active avoidance task and produced a less striking deficit in the retention of a one-way active avoidance task. These findings were later replicated in the rat (Krieckhaus, 1965). Thomas, Frey, Slotnick and Krieckhaus (1963) studied the post-operative acquisition of the two-way active avoidance learning task and reported mixed results: four of their eleven cats were completely unable to learn the task, while seven of them mastered the problem within the number of trials required by normal animals. (The significance of the distinction between acquisition and retention will be discussed in the following section.)

Cingulate cortex. The cingulate cortex lies above the corpus callosum on the medial side of the hemisphere, separated from the neocortex above by the cingulate sulcus. It merges with the hippocampal gyrus posteriorly and with the neocortex of the frontal lobe anteriorly. As noted by Papez, the cingulate gyrus receives its main afferent supply from the anterior nuclei of the thalamus and projects to the hippocampus via the cingulum bundle. Stimulation of the cingulate cortex also produces activity in the prefrontal and orbitofrontal regions of the neocortex (Dunsmore & Lennox, 1950). There are reciprocal connections with the anterior and other thalamic nuclei (including the dorsomedial). A strong projection to the inferior parietal lobule (IPL) in the post-central neocortex has been demonstrated in the monkey (Mesulam, Van Hoesen, Pandya & Geshwind, 1977). These authors, using the horseradish peroxidase technique, found that "the cingulate gyrus contained one

of the heaviest concentrations of labeled neurons in most cases" following injection of that substance into the IPL (p. 324).

The literature documenting the efforts of physiological psychologists to define the role of the cingulate cortex in learning and memory is confused somewhat by varying interpretations of the data by those authors (an objective review is available in Isaacson, 1974). Several experimenters have ascribed the learning deficit which follows cingulate lesions to an enhanced fear response. However, Kimble and Gostnell (1968), using two different behavioral measures, failed to find any support for this hypothesis. Lubar, Perachio, and Kavanagh (1966) suggested that incidental damage to the visual cortex could account for the deficits following cingulate lesions, but adequate control lesions (e.g., Kimble, 1968) and lesions which avoid damage to the visual cortex (Trafton, Fibley & Johnson, 1969) are adequate proof of the cingulate's role in the observed impairments (Isaacson, 1974). The essential findings on the effect of cingulate lesions on memory in the rat and cat are straightforward: such lesions impair the ability of these animals to acquire active avoidance conditioning (Peretz, 1960; McCleary, 1961; Thomas & Slotnick, 1962; Lubar & Perachio, 1965; Kimble & Gostnell, 1968; Trafton et al., 1969).

A number of relatively complex deficits have been noted after cingulate damage which resemble symptoms seen in human amnesia syndromes. These include disruption of the orderly sequencing of behaviors (in nest building and maternal behavior, Stamm, 1955; Slotnick, 1967), deficits in the temporal ordering of responding

(in runway problems and bar-press alternation: Barker & Thomas, 1965, 1966; Barker, 1967); and the failure to exhibit behaviors which were indicative of opium addiction (Marques, 1971). The last, especially, is supportive of the hypothesis voiced by some authors that cingulate-lesioned animals are unable to anticipate the emotional consequences of their behavior for both rewards and punishments (Glass, Ison, & Thomas, 1969; Isaacson, 1974).

Anterior cingulectomy has been termed the psychosurgical "operation of choice" for the treatment of severe obsessional and anxiety disorders (Lewin, 1961; Whitty, 1966). Whitty noted that one of the long-term effects of cingulectomy was "relative neglect of the impact of external events." Finally, Pechtel, McAvoy, Levitt, Kling & Massermann, (1958) concluded that lesions of the cingulate gyrus in humans resulted in, among other things, "amnesia for previous learning" and "impairment of new learning skills."

Discussion

The failure to transfer learning between hemispheres seen in cerebral commissurotomy preparations (animal and human) indicates that the storage of memories is a neocortical function (Geshwind, 1965). Generalized memory disorders, on the other hand, are only produced by bilateral damage to the diencephalic structures of the hippocampal system. It is evident that these structures in the circuit of Papez form part of a functional system which monitors the environment, matches incoming stimuli with representations of the organisms previous experience with similar stimulus configurations, activates the organism in the presence of potentially significant stimuli,

and finally, causes pertinent information concerning that stimulus to be presented to conscious awareness. It appears that there are two such systems in the human brain, each specialized to deal with a different type of information. The first, lateralized to the right hemisphere, performs the functions listed above with experiential data. The second, operating in the left hemisphere, deals with language and verbal concepts which may be based on gestalten that are assembled and stored in the contralateral system. All of the functions noted above are impaired, to a greater or lesser extent, in various manifestations of the amnesic syndrome.

The evidence suggests that some learning does not take place in amnesia victims, that is, memory traces are stored. However, the amnesic subject has difficulty gaining access to those memory traces when they are needed. More specifically, they are unable to recognize and select the appropriate memory trace in a given situation from the set of available traces. Access to the proper trace is facilitated with adequate cueing. It appears that the function of the hippocampal system is to assure the activation of appropriate memory traces based on the requirements of the situation. In the present formulation, significant (experientially based) memory traces have been designated by the superordinate term "generalized expectations." It appears that the hippocampal system is responsible for the generalizing of these expectations from one situation to another, similar, situation.

In lower forms, where survival is dependent on instincts, the identification of a significant stimulus may culminate in the release

of species-specific behaviors that are organized at a subcortical level. The elicitation of unlearned behavior sequences (related to feeding, fighting, fleeing and reproduction) by hypothalamic stimulation is well established and seems to be related to programs stored in the midbrain or brainstem (Isaacson, 1974). In humans, however, cortical functions are more important in determining the behaviors that insure survival.

Papez's circuit is an "anatomical identity which connects the temporal and cingulo-frontal cortex of both hemispheres" (Barbizet, 1963). Given the recently identified massive interconnection of the cingulate gyrus with the inferior parietal lobule (IPL), Papez's circle may be seen as forming a part of a larger cortical circuit (see Fig. 3). As such, it is in a position to directly modulate the activity of the two areas of the brain that are identified with the highest levels of information processing: the specifically human tertiary association areas of the prefrontal lobe and the IPL.

Information flow within this cortical-hippocampal circuit might be seen as follows: raw sensory data enter the system in the primary projection areas and are processed in the secondary association areas of the post-central cortex; as this information acquires meaning it is passed on to the temporal cortex and into the hippocampal circuit; here the meaningful bits are translated into a code that emerges in the cingulate cortex as memory indexing information; this, in turn, is referred to the IPL where it facilitates associations that fine-tune the continuing input into the system. This process continues until an adequate match is made and recognized at the

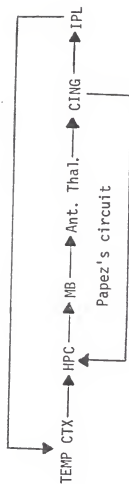


Figure 3. The position of Papez's circuit within a larger cortical circuit. (TEMP CTX - temporal cortex; HPC - hippocampus; MB - mammillary body; Ant. Thal - anterior nuclei of the thalamus; CING - cingulate gyrus; IPL - interior parietal lobule.

level of the temporal cortex. This match would take the form of a finished "gestalt" in the experiential system and a formal "concept" in the verbal system. With the appearance of such a match the temporal component would terminate the search process and relay the product to the contralateral system. Thus, the recognition of a gestalt might initiate the search for a related verbal concept or, conversely, a verbal formulation may trigger a scan for pertinent experiential associations. The description of these two complementary systems seems to provide adequate explanation for the qualitatively different types of memory which were described by Breuer and Freud and by Rapaport, respectively as noted at the beginning of this section.

Substantial support for the model described above may be found in a situation where hippocampal activity is induced from within the limbic system (rather than from the neocortex, as was the case in Penfield's experiments). Such is the case when amygdala stimulation produces after-discharges in the hippocampus. Halgren (1981) reviewed the effects of amygdala stimulation in conscious humans and noted that such stimulations sometimes produces "complex formed hallucinations, sometimes complete scenes as in a dream or vivid recollection and sometimes more vague, apparently similar to an intruding thought . . . and illusions of familiarity (deja vu)" (p. 345). Halgren suggested that it is the activation of distant normal tissue subsequent to amygdala stimulation which produces the resulting mental phenomena. He cites evidence that

Amygdala stimulation seldom evokes a mental phenomenon unless it also evokes an after-discharge . . . most amygdala stimulations, even if they evoke an after-discharge (AD), do not evoke any reported mental phenomenon . . . thus, there is no direct connection between amygdala activity and hallucinatory experiences. . . . Simultaneous recordings from multiple brain areas indicate that amygdala ADs seldom remain localized. Initial spread is to the ipsilateral hippocampus and hippocampal gyrus. AD may remain confined to these structures, in which case no mental phenomenon is necessarily evoked. Further spread is to the ipsilateral limbic cortex (orbital, insular and cingular) and diencephalon (especially the anterior nucleus of the thalamus, but also to the centre median, pulvinar and dorsomedial nuclei). ADs seldom spread to the neocortex, which may however desynchronize." (pp. 396-397, emphasis added)

These findings are congruent with the present formulation, which would interpret the appearance of "complex formed sensory hallucinations" following the stimulation described above as the result of hippocampal output evoking experiential memory traces in the posterior association cortex by way of the anterior thalamus and cingulate cortex. The appearance of identical "experiential hallucinations" following temporal lobe stimulation and limbic system ADs supports Penfield's contention that final common pathways in the temporal lobe may produce activity in the hippocampal system which ultimately results in the appearance of mental phenomena.

The hippocampal system is directly involved in the mechanics of learning. Hippocampal activity seems to assure that the organism attends to novel stimuli and sets the conditions which permit changes to be encoded into the neural models which form the central representations of those stimuli. Pribram and McGuinness (1975) suggested that such changes in neural representations "may be conceived as

changes of state, set, or 'attitude'" (p. 132). Such experientially based alterations in the disposition of the organism relative to a stimulus object, situation, or event provide an operational definition for the generic term "generalized expectation" as used in the present formulations. This type of memory appears to be the "idea" which Breuer and Freud believed to be of central importance in the etiology of psychoneurosis. (It will be suggested that it is precisely these generalized expectations, in this memory system, which will provide the answer to the question posed in the introduction: "What is to be changed in the process of psychotherapy?")

In addition to their mnemonic defects, amnesia victims with damage to the hippocampal systems also present anomalies in their affect and arousal. The latter may be traced to the failure of the hippocampus to trigger cortical activation (via the RAS) as it normally does in conditions of uncertainty or significance. The former seems to reflect the disruption of hippocampal modulation of the emotion/motivation processes by way of its interactions with other limbic structures and with the prefrontal areas (via the dorsomedial thalamus).

Interfaces and Interactions of the Monitoring Motivating, and Mobilization System

Pharmacological research with animals and humans has implicated the two classes of biogenic amines in the modulation of fundamental brain processes. The catecholamines dopamine (DA) and its metabolite norepinephrine (NE) have been associated with cognitive function and dysfunction (e.g., schizophrenia) while affective disorders seem to

involve an interaction between NE and the indolamine serotonin (5-HT). Histological researchers have identified six major monoamine systems in the rat brain (Fuxe, 1965; Fuxe, Hamberger & Hokfelt, 1968).

The nigro-striatal DA system originates in cell bodies in the substantia nigra whose axons extend through the lateral hypothalamus to terminate on cells in the caudate nucleus. This tract is known to regulate the activity of the ancient extrapyramidal motor control system.

The meso-limbic DA system originates in the ventral tegmental area of the pons and projects mainly to the septal area and related nuclei in the limbic forebrain. Dysfunction in this system is assumed by many to be the source of schizophrenic disorders.

The meso-cortical DA system is less well defined but appears to include projections from the ventrosegmental to the frontal cortex and from the substantia nigra to the anterior cingulate cortex (see Meltzer, 1979).

The ventral NE system originates in the reticular formation (medulla and pons) and ascends through the median forebrain bundle (MFB) to terminate on cells throughout the hypothalamus and amygdala. Stein, Wise and Berger (1972) suggested that this system primarily regulates motivational activities.

The dorsal NE system arises in the locus ceruleus in the pons and may supply up to 70% of the NE in primate brains (Redmond, 1979). The axons in this system ascend through the MFB and give off branches to the hypothalamus, the hippocampus and amygdala,

the septal area (which receives the bulk of these terminals), the anterior-ventral thalamus, the cingulate gyrus and the neocortex. Stein and Wise (1971) suggest that this dorsal NE system is involved in regulating cognitive activities.

The ascending serotonin (5-HT) system originates in the median raphe nucleus which is situated in the core of the reticular formation and receives collateral branches from the sensory nerves. 5-HT cells in the raphe have terminations throughout the central gray of the midbrain. Axons from the raphe also rise in the MFB and distribute to the same areas as the dorsal NE system, with the addition of terminals in the basal ganglia and more widespread distribution in the neocortex. This system seems to be most directly involved in regulating tonic arousal.

Brodie and Shore (1957) suggested that NE and 5-HT exert opposing effects that modulate a variety of CNS functions (e.g., sleep, appetite, sexual drive). It appears that these parallel systems control behavior by reciprocal action in balanced systems. While functional specificity is determined by the neural circuitry involved at a given anatomical level, the cumulative effects of specific functional outcomes produced a preponderance of one or the other transmitter seem to be consistent and to result in coordination across levels. It appears that a preponderance of the indolamine 5-HT, for example, results in the release of tonic mobilizing energy at the brainstem level, the suppression of ongoing behavior at the hypothalamic level, the identification of "negative reinforcement" at the limbic system level, and

cognitive patterns consistent with the goals of orienting at the neocortical level. An opposite pattern is evident when the catecholamines predominate. The specific systems involved in these functions will be described in the following sections.

The Biochemistry of Emotion, Motivation, and Learning

The fundamental prerequisite for adaptive behavior is a system to sort environmental inputs and pair them with appropriate responses. The more primitive life forms must rely on the experience of their species, accrued over evolutionary history and transmitted genetically, to accomplish these tasks. The adaptability of such forms is strictly limited by the repertoire of sensory discriminations and motor response sequences they are programmed to perform. Kety (1972) noted that adaptability would be greatly enhanced if the organism could learn to determine and preserve those sensory, evaluation, and response patterns which, in the individual's own experience, provided the ultimate survival advantage. He suggested that neuronal and neurochemical mechanisms which utilized constant reference to a small number of inborn values or states would allow the nervous system to become increasingly elaborate and effective in performing these functions. Kety postulated that only three such inborn states should be required: arousal, pain, and pleasure. He proposed that these mechanisms would interact to produce an emotional state, consisting of increased arousal and the activation of particular circuits, with a resulting drive to approach or avoid the confronting stimulus. Arousal would accompany both pleasure and pain but might occur in the absence of either in response to novel stimuli or to

inputs either genetically or experientially endowed with significance to the organism. The emotional state would be accompanied by the "intercbral release of a trophic neurogenic substance . . . [which would permit] transcription into more permanent form . . . to present and immediately preceding states of neuronal activation where the outcome had been significant for the organism" (Kety, 1972, p. 71).

Simply put, the results of the organism's adaptive efforts (i.e., positive or negative reinforcement) might produce a characteristic biochemical signature within these circuits which reflected the consequent affective status of the organism in that situation. These data could then be encoded along with the memory of the situational context. If that same stimulus configuration was confronted again at a later time the encoded emotional information would cause the biochemical pattern to be replicated in these circuits, the effect of which would be to recreate the original emotional state to motivate the organism appropriately based on the original experience.

Extensive work by Stein and his colleagues indicates that the circuits involved include a noradrenergic median forebrain bundle reward/behavior-release system which is antagonized by the serotonergic periventricular system (PVS) which functions as a punishment/behavior-suppression mechanism. Stein, Wise and Berger (1972) summarize experimental evidence which implicates these systems in the release and suppression of unlearned behavior:

Briefly, electrical stimulation of the median fore-brain bundle . . . elicits species-typical consummatory responses, such as feeding and copulation, which

produce pleasure and permit the satisfaction of basic needs. Similar effects are produced pharmacologically by potentiation of the noradrenergic (or blockade of the serotonergic) activity of the median forebrain bundle. On the other hand, electrolytic lesions of the median forebrain bundle cause severe deficits in goal-directed behavior and the loss of consummatory reactions; again, similar effects are produced by pharmacological blockade of noradrenergic function or potentiation of serotonergic function. (Stein et al., 1972, p. 82)

These authors suggest further that the NE system produces positive feedback which facilitates ongoing behavior that was rewarded in the past and the 5-HT system produces negative feedback which terminates behavior that was unsuccessful or punished. Experimental evidence supports their contention that these systems also mediate learned behavior. Wise, Berger, and Stein (1970) demonstrated that drugs which deplete central stores of serotonin, (and drugs which produce blockade of serotonergic receptors) significantly reduced a shock-induced elevation of brain serotonin levels significantly increased the conditioned behavioral suppression. None of the drugs effected the behavior of unshocked control animals. The complementary role of NE was evident in a study where monkeys received bilateral stimulation or lesions of the locus ceruleus (the source of the dorsal NE system). Redmond (1979) reported that bilateral locus ceruleus stimulation elicited behaviors which were associated with increased fear. Animals with bilateral locus ceruleus lesions subsequently rose in their social hierarchies because they lost their fear of previously dominant animals (and humans): they showed increased motor activity, increased social aggressiveness, and decreased retreat from threat from pre-lesion levels while retaining

normal responses to actual pain. Arbuthnott, Fuxe, and Ungerstedt (1971) presented evidence that all of the "positive reinforcing" (self-stimulation) points are within the ventral NE system. Stein and Wise (1969) demonstrated (with permanently implanted push-pull cannulae) that "rewarding" self-stimulation of the MFB caused increased synthesis and turnover of NE and a marked increase in the release of radioactively labeled NE into perfusates of the amygdala and hypothalamus.

Isaacson (1974) suggested that the almost total lack of fear and aggression responses in animals after bilateral amygdectomy reflects a decrease in the ability of environmental stimuli to elicit reactions from the organism. Increased 5-HT activity has been associated with increased fear and decreased aggression while decreased NE activity has been associated with decreased fear and increased aggressiveness. It appears that in lower forms these systems mediate the release or suppression of instinctive behavior at the level of the hypothalamus. It follows from all of the data presented above that the ability to learn from experience, a prerequisite for self-determined behavior, involves an integration of emotional experience and memory which is based on an interaction of NE and 5-HT in the amygdala.

Emotion, Amygdala Circuits, and Memory

The role of the amygdala in emotional processes, established by Kluver and Bucy in 1938, has been assumed to be affected through this structure's close relationship with the hypothalamus. The amygdala seems to direct behavior toward biological goals (Halgren,

1981) and related to survival needs, including defensive and aggressive behaviors, sexual activity, and feeding (Isaacson, 1974). In lower forms these processes might depend on a simplified (instinctive) form of memory in which stimulus and response are yoked (Pribram & McGuinness, 1975). In addition to mediating emotional states the amygdala is involved in the analysis of reinforcement contingencies. Amygdala lesions have been shown to produce impaired recognition of stimuli associated with rewards (Weiskrantz, 1956; Schwartzbaum, Thompson & Kellicut, 1964; Jones & Mishkin, 1972) and inability to respond appropriately to changes in the magnitude of rewards (Schwartzbaum, 1960).

The more recent discovery of strong anatomical interconnections between the amygdala and the neocortex (Aggleton, Burton & Passingham, 1980; Herzog & Van Hoesen, 1976; Turner, Mishkin & Knapp, 1980) allows for the involvement of this structure in higher levels of mental processing and memory. Kessner (1981) suggested that long-term memory "consists of a set or bundle of traces, each representing some attribute or feature of a learning experience." He postulated that "the amygdala mediates the encoding, storage, and retrieval of specific emotional attributes often associated with reinforcement contingencies in specific situations" (p. 332). In a test of this hypothesis Kessner and Conner (1974) showed that five seconds of bilateral subseizures level electrical stimulation of the amygdala (which disrupts the normal functioning of that structure) following footshock in a passive-avoidance paradigm resulted in amnesia for that training experience. Implanted and unoperated controls without

such stimulation demonstrated excellent memory for the learning experience. Kessner interpreted this result as the failure to encode the negative affect associated with the experience.

In order to discriminate the relative contribution of the amygdala and the hippocampus to these phenomena Baker, Kessner, and Michal (1981) took advantage of the fact that suitable reminder cues often serve to facilitate existing memories and thus enhance recall. Rats with electrodes implanted in the amygdala or hippocampus and unoperated animals received a single training trial with footshock (FS) while licking a water tube in a goal box. Retention was evaluated 24 hours later as an increase in latency to enter the goal box and lick the tube at least ten times. Following this first retention test four of the groups received a reminder cue (non-contingent FS) in a different environment, followed immediately by hippocampus or amygdala stimulation or no stimulation. Twenty-three hours later all groups were tested a second time for retention of the passive-avoidance learning in the original apparatus. Operated and nonoperated controls that received a reminder cue but no brain stimulation exhibited a marked increase in latency on the second (relative to the first) retention test, demonstrating that the reminder cue effectively enhanced retention of the aversive experience. Conversely, operated and nonoperated controls which did not receive a reminder cue showed a decrease in latency on the second test, indicating that some extinction had taken place due to re-exposure to the original apparatus during test number one. Animals whose amygdala function was disrupted by electrical stimulation following the reminder

cue showed a decrease in latency on the second retention test as compared to the first, and thus resembled the groups that never received a cue. By contrast, animals which received hippocampal stimulation following the reminder cue exhibited an increase in latency, similar to the control animals which benefited from the reminder FS. Kessner (1981) concluded from these results that "amygdala stimulation disrupted the encoding of negative affective attributes associated with the reminder FS negating its efficacy in enhancing subsequent retention. In contrast, hippocampal stimulation had only a small effect and did not totally disrupt the efficacy of the FS reminder" (p. 336). It seems, therefore, that the amygdala is selectively involved in the memory of emotional experience, at least for the negative affect associated with passive-avoidance learning situation.

Kessner (1981) reviewed several studies which suggested that the amygdala was not involved in the encoding of positive affective attributes. However, he cites evidence that amygdala stimulation does appear to disrupt retention when there is a magnitude of reward effect (i.e., fewer errors for the expectation of a greater magnitude of reward). Kessner concluded from the studies reviewed above that "the amygdala encodes, stores, and retrieves both positive and negative emotional attributes of a specific memory, providing the input is of sufficient intensity to elicit a relatively strong emotional reaction. . . . Different neural systems (e.g., hippocampus) would encode other attributes (e.g., environmental context) of the same specific memory" (1981, p. 340).

Mishkin and Aggleton (1981) reviewed data which demonstrate that the amygdala receives highly processed sensory information from all of the secondary and polymodal association areas of the posterior neocortex in addition to its reciprocal connections with the hypothalamus. They suggested that these connections provide a mechanism for complex stimuli to become integrated with, and later, to evoke emotional responses which are organized at the level of the hypothalamus.

Smythes (1966) suggested that the hippocampal system may lay down memories and the amygdala system may determine what memories are to be laid down. While this may overstate the case somewhat, it is clear that these two functional systems work synergistically to provide the organism with pertinent information from its past experience which is capable of motivating and facilitating appropriate responding based on the requirements of the situation. The septal area appears to play an essential role in the interaction of the amygdalar and hippocampal systems and may integrate their activity with that of the brain's arousal systems.

The septal area is interposed anatomically and functionally between the amygdala and hippocampus (via the stria terminalis and fornix, respectively) and has a reciprocal relationship with both (Swanson & Cohen, 1976). The septum is connected with the brainstem reticular formation (via the MFB) and is in a position to modulate the activity of the ARAS through its connection with the habenula (via the stria medularis), which is a station between the RF and ILTN. (All of these anatomical relationships are illustrated

in Fig. 2). The septo-hippocampal axis has received the most attention to date.

Based on their micro-electrode recording studies Edinger and Siegal (1976) suggested that

Activity in adjacent groups of hippocampal efferent pyramidal cells could result in the discharge of a septal neuron. The activation of this neuron will excite the inhibitory interneuronal network [within the septal area] to block activity in other portions of the septum. The septum therefore acts as a filtering mechanism to permit transmission of information only from that portion of the hippocampus whose pyramidal neurons are most active at that point in time. Information transmitted from less active areas of the hippocampus will be suppressed by the inhibitory network of the septum. (p. 249)

The septal area appears to have a similar effect on the interneuron population of the hippocampus. Lynch, Rose and Gall (1977) conclude from their anatomical investigations that "septal contacts on [hippocampal] interneurons modulate their activity and thus allow the 'biasing,' in effect, of the response of the hippocampal neurons to their excitatory inputs . . . the septal projections may serve to modulate the response of the hippocampus to the activation of its massive afferent input from the entorhinal cortex" (p. 17). Thus, the septal area is in a position to integrate the activity of the brain's memory, emotion, and arousal systems and the available evidence supports the suggestion of such a role for this structure. This arrangement would permit the amygdala, acting through the septal area, to focus the hippocampal system's memory search on associations which have immediate (emotional) significance for the organism.

The identification of emotionally significant stimuli in phylogenetically lower forms may result in the release of species-specific responses at the level of the hypothalamus, but in higher forms the neocortex is more involved in motivating behavior. It is assumed here that the more recently developed systems which provide the substrate for higher mental processes must be programmed in some way to insure survival. It appears that biochemically mediated mechanisms may have evolved in parallel over the more ancient control circuits to perform this function. Stein and Wise (1971) suggested that the dorsal NE system was involved in the regulation of cognitive processes. Several lines of evidence, taken together, strongly suggest that the cingulate cortex and NE participate in the integration (encoding and decoding) of emotional experiences with memory to facilitate adaptive functioning at the highest levels:

1. Based on the review in the previous section it was hypothesized that the cingulate cortex is the final station in a hippocampal memory circuit which performs memory indexing functions.

2. The cingulate cortex is interposed anatomically between the prefrontal lobe and the inferior parietal lobule (IPL) and is thus in a position to coordinate the actions of these two highest centers of information processing.

3. Animals with cingulate lesions are unable to acquire avoidance learning (see previous section). Ison and Thomas (1969) concluded from their studies that cingulate lesions "dissociated conditioned emotional goal responses from instrumental performance" (p. 17). Ward (quoted in Isaacson et al., 1971, p. 232) reported

that monkeys with cingulate damage treat their companions like inanimate objects, which he interpreted as a "loss of social consciousness."

4. Miessler (1967) noted that the content of the complex hallucinatory experiences reported by Penfield's subjects after electrical stimulation of the right temporal cortex was not surprising: "What is surprising is only the vividness of the imagery" (Miessler, 1967, p. 169). Whitty (1966) reported that, for one to three days postoperatively, patients who had undergone anterior cingulectomy experienced "increased vividness of thoughts and images so that a subjective difficulty is experienced in distinguishing between thoughts and exterior happenings" (p. 404).

5. The cingulate cortex receives projections from the brainstem ascending 5-HT and dorsal NE systems and has the highest density of NE terminals in the cortex (Fuxe et al., 1968).

6. Redmond and his colleagues (see Redmond, 1979) reported that monkeys with bilateral locus ceruleus lesions showed an "absence of emotional responses to threat" (p. 158). Encephalitis lethargica is a disease which affects the brainstem and the periaqueductal gray area (which contains the locus ceruleus) in particular. Penfield (1975) noted that postencephalic patients often developed an obsessive-compulsive syndrome: such patients were "preoccupied with compulsive thoughts, compulsive utterances, and compulsive behaviors to an extent that often caused severe disability" (p. 98).

7. In obsessive-compulsive illness certain thoughts and/or actions acquire an inappropriate level of significance for the individual and social functioning is impaired. Cingulectomy is the psychosurgical "operation of choice for the classical syndrome of obsessive neurosis;" after surgery "the obsessive thoughts retreat gradually into the background and the drive behind them lessens" (Lewin, 1961). Humans who have undergone cingulectomy show some disinhibition of behavior (but decreased aggressiveness) and seem to neglect the emotional impact of external events (Whitty, 1966).

Discussion

It is evident that the cingulate cortex is involved in the coordination of emotional, attentional and cognitive processes. It appears that this structure modulates the infusion of emotional significance into ongoing perceptual and/or associational operations and influences the allocation of neural mobilizing energy, thus permitting normal emotional reactivity and appropriate inhibition of behavioral and cognitive activity. While it is not possible at present to sort out the complexities of 5-HT/NE interactions across brainstem, cortical, and right/left dimensions, the available evidence suggests that the cingulate gyrus evolved as a cortical extension of those brainstem control mechanisms. In the context of functional systems, the cingulate cortex is in a position to encode emotional data from the amygdala-orbitofrontal circuit into neural models being "indexed" by the hippocampal memory system.

Biochemical and Electrophysiological Aspects of Cortical Mobilization Processes

It appears that the NE and 5-HT systems interact to control the energizing output of the reticular formation. At the brainstem level stimulation of the raphe' (5-HT) nuclei produce calmness and EEG patterns similar to those of normal sleep, while damage to these nuclei result in increased motor activity (see Fawcett, 1975). The raphe' nuclei are thought to be the primary site of action in morphine-induced catalepsy (see Broekkamp & Lloyd, 1981). Kety (1972) summarized pharmacological evidence which implicates NE in the modulation of arousal and sedation. Evidence to be reviewed below suggests that, at the neocortical level, the 5-HT system supports a pattern of indiscriminate cortical arousal which facilitates gross sensitivity at the expense of complex analysis. Another system mediated by DA seems to permit the focusing of attention and may be the means by which the frontal lobes recruit and organize cognitive activities in the post-central cortex.

Surgical ablation of the prefrontal lobes is sometimes performed to relieve otherwise intractable pain. This operation is not a specific cure for pain, however, but a cure for "suffering," the source of the pain and its threshold remain unaltered. It is the person experiencing the pain that is altered by this psychosurgical intervention. Petrie (1952; 1960; 1967) found that the changes in pain tolerance were paralleled by striking differences in the subjectively perceived intensity of sensation other than pain. She suggested that the personality and perceptual tendencies

of a person before and after prefrontal lobotomy exemplify the extremes on a continuum of "perceptual reactance" which can be seen in the normal population. Petrie (1960; 1967) administered her kinesthetic figural aftereffects test to a variety of normal and abnormal populations and demonstrated that, after repeated tactile stimulation of the fingertips, some people consistently overestimate (augment) the size of a standard stimulus while others consistently underestimate (reduce) its size. Reducers tolerate pain well and augmenters do not. Petrie argues that augmenters and reducers are displaying basic differences in their methods of perceiving the environment.

Several investigators studying visual evoked potentials to light flashes have noted that some subjects showed a reduction in the amplitude of these cortical responses as stimulus intensity increased, a phenomenon which Kamphuisen and van Leeuwen (1968) called "paradoxical diminution." Buchsbaum and Silverman (1968) reported a significant correlation between flash visual evoked responses and performance on Petrie's kinesthetic figural aftereffects test: augmenters showed an increasing cortical response as stimulus intensity increased while reducers showed a leveling off or decrease in the amplitude of their cortical responses. This finding was replicated by Spilker and Callaway (1969) using different stimuli and different electrode placement. von Knorring, Espvall and Perris (1974) demonstrated empirically that reducers classified by visual averaged evoked responses had significantly higher pain thresholds and pain tolerance levels than augmenters.

By altering the cortical evoked response paradigm so that the second of a pair of responses could be expressed as a function of the first Pribram (1967) was able to make important inferences about the organization that is imposed on incoming information:

When a double click or a double flash is used to evoke a neural response, the amplitude of the second of the pair of responses serves as an indicator of the duration over which a part of the system is occupied in processing the first of the pair of inputs. A depression in the amplitude of the second of the responses thus indicates a longer recover--a longer processing time for a signal within the channel. Such an increase in processing time effectively desynchronizes the channel to repetitive inputs: fewer fibers are available for processing any given signal in the series. Prolongation of recovery thus reduces redundancy in the channel. At any moment more information can be processed. . . . Thus the rate of information processing is enhanced. (Pribram, 1967, p. 460)

Augmented redundancy in information processing channels would mean that more neurons were available to fire in a stimulus-linked fashion. Thus, the sensitivity of the organism would be increased (e.g., decreased pain tolerance, increased subjective experience of pain). Since information tends to be "chunked" in this mode there would be a decrease in the focusing of attention on details and decreased articulation of experience. Conversely, reduced redundancy in information processing channels would leave fewer neurons available to fire in a stimulus-linked fashion, thus reducing the sensitivity of the organism; bits of information would tend to be separated in this mode permitting increased focusing of attention on details and increased articulation of experience. It will be noted that the augmentation mode would favor the performance of cognitive tasks associated with the orienting response (i.e.,

stimulus identification) while the reduction mode would facilitate the sequential information processing and abstraction of detail associated with problem-solving and language processes.

A novel stimulus (information plus uncertainty) "disinhibits and gains access to large number of neurons indiscriminantly throughout the neocortex" (Kety, 1972, p. 71). Pribram and McGuinness (1975) reviewed evidence which indicates that the source of the generalized cortical arousal associated with orienting is to be found in the serotonergic nuclei of the brainstem. The searching and sampling of the orienting process is terminated when the stimulus is identified and registered in memory. At this point uncertainty is resolved. If the situation registered in the neuronal model of the identified stimulus has no built in "demand" characteristics the organism may habituate to the stimulus and proceed to ignore it. However, if the neuronal model generates important expectations related to the stimulus, then cortical activation systems which facilitate perceptual and motor readiness to respond will be engaged. In contrast to the indiscriminate cortical arousal associated with orienting and perceptual augmentation, these activation systems produce a highly organized pattern of cortical activity. Pribram and McGuinness (1975) reviewed evidence which indicates that the mechanism and pathways involved in controlling these activation systems are dopaminergic, and that their operation is reflected in the phenomenon of the contingent negative variation, or "expectancy wave."

The characteristics of the contingent negative variation (CNV) were reviewed by Cohen (1974). Briefly, the CNV is a special form of cortical evoked response consisting of a gradually developing wave of negative potential which originates in the frontal lobes and sweeps posteriorly over the cortex whenever there is a stimulus-response contingency or expectancy built into a situation. This wave becomes abruptly positive when the required perceptual or motor response is executed. The amplitude of the signal is directly related to the reinforcement ratio, with peak amplitude at 100% reinforcement. Reaction time is shortest following high amplitude CNVs. Perhaps the most interesting characteristic of the CNV is the fact that it responds to verbal instructions: the waves disappear when the instruction which produced the expectancy is countermanded, and fail to appear when the subject is told in advance that the contingent signal will not be forthcoming. The association between perceptual reduction processes, the CNV, and dopamine is strengthened by the finding that evoked potential reducers have increased levels of homovanillic acid (a dopamine metabolite) in the cerebral spinal fluid (Gottfries et al., 1974).

The Functional Elements of the Personality Structure

It has been assumed here that the phylogenetic transition from instinct-based responding to self-determined behavior required the evolution of new mechanisms to insure the survival of the individual and the species. Specifically, it was hypothesized that automatic neural systems were needed to: (1) Monitor the environment for significant stimuli; (2) Motivate the organism to respond in the presence of such stimuli; and (3) Mobilize the appropriate

psychological operations to determine the form of that response. It was postulated that these mechanisms would be arranged in functional systems (as defined by Luria, 1973a) and that these central organizing factors would form the infrastructure of personality. The brain mechanisms which appear to satisfy these requirements will be outlined below. It will be proposed that these systems form the basic functional elements of the personality structure. Supporting evidence from animal studies of learning and memory will be presented at the end of this section.

The Problem-Solving / Response-Generating System

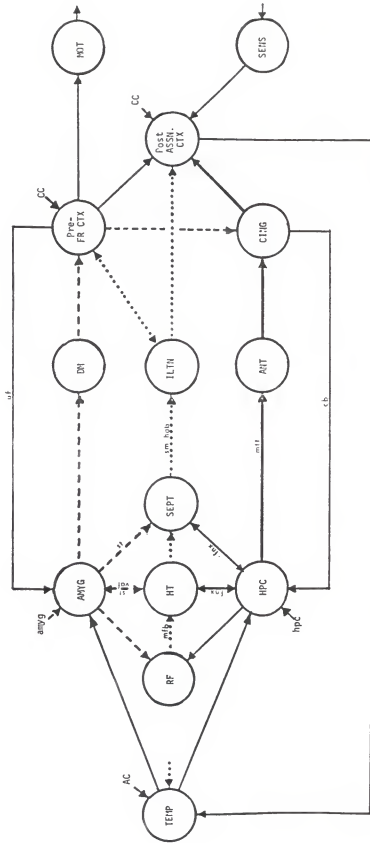
It is evident that the psychological operations which generate considered responses in a given situation take place in the neural tissue of the association areas in the post-central cortex of the left cerebral hemisphere. These mechanisms normally have access to, and employ the products of, mechanisms lateralized in homologous areas of the right hemisphere. Both of these areas solve problems through a process of categorization, but they arrive at their solutions in different ways. The right hemisphere is specialized to perceive overall patterns in input; it solves problems through a convergence of information, synthesizing basic units into meaningful gestalts. The left hemisphere shares these spatial abilities to some extent, but they have been superseded by more complex skills. The dominant hemisphere has been genetically prepared to analyze information along a temporal dimension and this ability allows mental activity to escape from the bounds of the immediate spatial context. This freedom, in turn, permits the mental manipulation

of externally provided symbols and aids (e.g., language and rules of grammar, mathematical tables and formulas). The sequential operations involved in abstract reasoning, logical analysis, and propositional speech are made possible by the temporal acuity of the left hemisphere. The orderly selection (programming) of these operations depends on the integrity of the tertiary association zones in the dorsolateral area of the prefrontal lobe.

Three types of information are required at these neocortical levels in order to guarantee that they will perform their problem-solving tasks appropriately in survival situations. This information is provided by three functional systems that were outlined above. Each of these systems has limbic, thalamic, and cortical components (see Fig. 4).

The Memory System

Input to the hippocampal memory system consists of processed sensory data and/or the products of ongoing cognitive activity. This information is passed from the post-central association areas to the temporal lobe into the entorhinal cortex. Hippocampal output emerges in the cingulate cortex as memory indexing information which is passed on to the IPL where it facilitates access to memory traces which are associated with the input stimulus. These associations finally emerge in consciousness as formal percepts or concepts which provide context information and generalized expectations to the problem-solving/response-generating systems. Signals representing emotional information are passed from the amygdala to the septal area where they modulate or focus hippocampal memory



Key to the schematic representation of the proposed model of the physiological substrate of personality. Post connections are reciprocal; arrows indicate pathways emphasized in the text. Heavy black lines indicate memory indexing. Information from the Hippocampal Monitoring System, Dashed lines indicate emotion/reinforcement information from the amygdalar Motivating System. Dotted lines indicate activating information from the reticular formation Mobilizing System. AMYG--amygdala; ANTG--anterior temporal lobe cortex; DN--dorsomedial thalamic nucleus; Pre-FR CTX--prefrontal cortex; MOI--motor cortex; BG--basal ganglia; TEMP CTX--temporal lobe cortex; AMIS--autonomic nervous system; ILT--hypothalamus; SEPT--septal area; RF--reticular formation; ILTN--intralaminar thalamic nuclei (includes all nonspecific thalamic nuclei); Post ASSN CTX--postcentral association cortex (includes secondary association areas and inferior parietal lobule); SENS--primary projection sensory cortex; HPC--hippocampus; hpc--contralateral hippocampus; hpb--medial body; ANI--anterior thalamic nuclei; CITG--cingulate gyrus; CC--corpus callosum; AC--anterior commissure; mf--uncinate fasciculus; cb--ventral amygdalofugal fibers; sc--striatal terminals; sm--striatal medullaris; sin--sinus medullaris via habenula; mfb--medial forebrain bundle; fax--fornix; HT--mammothalamic tract.

Figure 4. Schematic representation of the proposed model of the physiological substrate of personality.

coding/decoding operations through a two-way septal-hippocampal interaction. The memory indexing process is further modulated or programmed by processed motivational input from the prefrontal lobe to the cingulate cortex. This system accomplishes three principal tasks in the course of its operation: (a) it monitors incoming stimuli and matches them against cortical representations of the organism's previous experience with similar stimulus configurations; (b) when a potentially significant stimulus configuration is encountered the system activates the organism by switching on the Mobilization System; and finally, (c) it causes pertinent information related to those stimuli to be presented to conscious awareness.

It appears that there are two such systems in the human brain, each specialized to deal with a different type of information. The first, lateralized to the right hemisphere, performs the functions listed above with experiential data. The second, operating in the left hemisphere, deals with language and verbal concepts. It is probable that environmental stimuli trigger an initial search in the experiential (right hemisphere) system. (It may be noted that these right hemisphere processes would be unconscious and that their products might be excluded from consciousness.)

The Motivating System

The Motivating System is centered on the amygdala. This structure receives processed sensory information from all of the sensory modalities and is interconnected with the entire prefrontal lobe both directly (via the uncinate fasciculus) and indirectly (by way of the dorsomedial thalamic nuclei). It also has strong

reciprocal connections with the hypothalamus (via the stria terminalis and the ventral amygdalofugal fiber system) and with the septal nuclei (via the stria terminalis).

The amygdala is involved in the intergration of information from the internal and external enviroments which relates specifically to the survival of the individual and its ability to reproduce. Based on such an integration, the amygdala attaches motivational significance to previously neutral stimuli by associating those stimuli with their internal consequences. The amygdala produces the signals which permit the positive and negative attributes of an experience to be encoded in memory through an interaction with the hippocampus (via the septal area). When that memory trace is reactivated on a later occasion the amygdala responds to its encoded emotional and reinforcing attributes, computes the reinforcement value of the present stimulus in light of the immediate internal status of the organism, and participates in focusing the hippocampal systems on significant memory traces. Qualitative and quantitative motivational information is relayed from the amygdala to the orbital-frontal cortex where it is translated into a subjective experience (.e.g, fear, anger, anxiety, etc.) of appropriate intensity. The tertiary association area in the dorsolateral prefrontal cortex responds to this experience and will attempt to resolve it by programming the post-central problem-solving mechanisms to formulate a behavioral response to the stimulus. The amygdala may also initiate activity in the sympathetic and parasympathetic control mechanisms in the hypothalamus to prepare the organism physically

to deal with the stimulus and might activate the pituitary-adrenal "rapid alarm" system.

The Mobilization System

The cortical mobilizing system is based on the brainstem reticular formation (RF). Signals from this mechanism lower the activation threshold of neurons it projects to. The activity of the RF is modulated by biochemically mediated forebrain systems whose descending influences reach the RF through the hippocampus (HPC) and amygdala (AMYG). Ascending RF pathways pass through the hypothalamus and septal areas and terminate on the nonspecific thalamic nuclei (e.g., ILTN).

Descending influences from the prefrontal lobe modulate the activity of the thalamic reticular system and in this way direct the activation of specific cortical systems. This is accomplished through an interaction between the nonspecific thalamic nuclei and the thalamic association nuclei. In this manner the frontal lobes are able to recruit and program cognitive operations in the post-central cortex in accordance with intentions.

The Memory, Motivating, and Mobilizing systems supply the neocortex with memory indexing information, qualitative and quantitative emotional data, and activating impulses, respectively. Each of these categories of information is essential for normal functioning. Damage within any one of these functional systems results in a different syndrome of specific clinical deficits. The manifestation of these deficits may vary with the location of the damage within the system.

Each of these systems evolved from more primitive mechanisms which regulated the emission (in the presence of releasing stimuli) of unlearned (instinctive) behavioral sequences related to the survival functions of feeding, fighting, fleeing, and reproduction. In their evolved form these systems allow the decoupling of stimulus and response, thereby permitting the neocortex to determine behavior, but they continue to insure that an adequate response is emitted.

Learning and Memory: Animal Studies

The model indicates specific functional/anatomical mechanisms which could account for the sometimes puzzling deficits seen after different limbic system ablations in experiments performed by physiological psychologists.

Animals with hippocampal lesions are sometimes the same and sometimes different from normal animals in the performance of tasks for appetitive rewards (Isaacson, 1974, ch. 5). Such conflicting results have made it difficult to define a specific role for the hippocampus in memory functions. Studies of human amnesia victims (reviewed in the previous section) indicate that their amnesic deficit reflects an inability to select the appropriate memory trace from the set of available traces, although memories continue to be laid down in the cortex. A naive animal (with hippocampal damage) in a strictly controlled laboratory situation may store only one memory trace (or "hypothesis") for that situation and not be troubled by competing memory traces. There have been many reports that animals with hippocampal damage are able to learn a simple discrimination problem (Isaacson, 1974, ch. 5).

However, when the situation requires that the animal select from more than one possible hypothesis, as in successive or simultaneous discrimination problems, hippocampal animals are impaired relative to controls (Kimble, 1961, 1963). Similarly, naïve hippocampal animals can learn to bar-press for rewards under continuous reinforcement (CRF) conditions but are impaired when they are transferred to a partial or intermittent schedule (e.g., the DRL). Schmalz and Isaacson (1970) demonstrated that it is the change in schedules that is debilitating: Hippocampal animals trained from the outset using only the DRL contingencies were not impaired on that task. Winocur and Mills (1970) found that previous experience impaired the performance of hippocampal animals only when the preceding task was related in some way to the new problem; unrelated training did not interfere. Thus, similarity between situations actually hinders hippocampal animals rather than helping them. Isaacson (1974) interpreted such results as the inappropriate transfer of strategies or the fixation of predominant behavioral dispositions, but the present formulation would stress the hippocampal animals' inability to select between competing memory traces because they do not receive memory indexing information at the cortex.

Five experimental paradigms have been used extensively in investigations of the affect of limbic system manipulations on learning and memory. In the passive avoidance task an animal is punished for making a response (e.g., receives a shock while drinking from an electrified water tube) and must learn to avoid the

punishment by withholding that response (Isaacson, Douglas, Lubar & Schmaltz, 1973, note that the inhibition of a response is actually an active process)]. In the one-way active avoidance problem the animal must learn to actively avoid punishment (e.g., footshock [FS]) by making a specified response (e.g., jump over a hurdle in response to a conditioned stimulus [CS] which signals an impending FS). In the two-way active avoidance task the animal must jump between the two compartments of a shuttle-box on alternate trials in response to a CS in order to avoid punishment. Isaacson et al. (1971), point out that this situation produces a conflict between an active- and a passive-avoidance response: on any given trial the animal must leave the compartment it is in to avoid the signaled FS (active-avoidance) and must enter the compartment in which it was shocked on the previous trial (passive-avoidance). In the differential reinforcement of low rates of responding (DRL) situation the animal must learn to withhold responses for a pre-determined amount of time after the last response before a response will be rewarded. On the fixed interval (FI) reinforcement schedule normal animals learn to stop responding in the first half of the interval following a reinforced response and to slowly increase their rate of responding in the second half of that interval. Continued responding in the first half of the interval is considered to be a perseveration error; higher than normal rates of responding in the second half of the interval are considered anticipatory errors.

Animals with hippocampal or septal area damage show identical alterations in their performance of all of these tasks (Isaacson et al., 1971). They are impaired in the acquisition of passive and one-way active avoidance problems; they perform better than controls on the two-way task; they show perseverative over-responding on the FI operant schedule and fail to obtain reinforcements in the DRL situation because of this over-responding tendency (Isaacson, 1974; Grossman, 1976). Each of these will be considered in turn.

It was noted in the last section that electrically induced disruption of amygdala function immediately after training in the passive avoidance (PA) paradigm resulted in a learning deficit for that task which mimicked the deficit found after amygdectomy. It was hypothesized that the deficit reflected the failure to encode the negative attributes of that situation in memory. The evidence indicates that the septal area and hippocampus participate in this encoding process. Animals with septal lesions also show a deficit in this task (McCleary, 1961). Grossman and his colleagues have succeeded in selectively transecting the various connections of the septum using a specially designed retractable wire encephalotome (see the review by Grossman, 1976). They found no PA deficit following transection of the fornix (FNX), the medial forebrain bundle (MFB), or the stria medullaris (SM), but cutting the stria terminalis (ST) duplicated the PA deficit seen after septal (and after amygdalar or hippocampal) lesions. Thus, it appears that it is the isolation of the amygdala from the septo-hippocampal integrating mechanism and the subsequent failure to encode the negative

attributes of an experience in memory which produces the PA deficit (rather than "perseveration" or a "loss of inhibitory control" as assumed by many authors, e.g., McCleary, 1966). That the hippocampus (HPC) is essential in this encoding process is indicated by the finding that animals trained on the PA task before bilateral HPC ablation were not impaired in the retention of the learning after surgery (Wishart & Mogunson, 1970), while such lesions impair the post-surgery acquisition of that problem (Isaacson & Wickelgren, 1962).

Transection of the FNX, but not of the ST or MFB, duplicated the pattern of responding seen on the FI schedule after septal and HPC damage, and partially replicated the disinhibitory affects of such lesions in the DRL paradigm (Grossman, 1976). Grossman believed that these results were "due specifically to a disruption of septo-hippocampal connections" (1976, p. 405). The present formulation would emphasize the role of the septum in modulating hippocampal control of the Mobilization system via the RF. Septal lesions block the theta rhythms normally seen in the HPC following and alerting stimulus (Smithies, 1966). Failure of the HPC to inhibit the RF would be expected to result in increased tonic mobilization and "over-responding," even when such behavior is inefficient.

The puzzling superiority of animals with HPC or septal lesions over controls in acquiring two-way active avoidance learning (Isaacson, Douglas & Moore, 1961; King, 1958) is probably due in part to the peculiarities of the shuttle-box situation which gives an advantage to animals with a PA deficit. Grossman (1976)

noted that rats with FNX cuts or septal lesions were hyperactive and avoided mainly by shuttling spontaneously between compartments, expending a great deal of energy in the process. The fact that animals with MFB cuts were not hyperactive and learned to respond appropriately to the CS suggested to Grossman that the altered responding by HPC and septal animals in this paradigm was due to "an interruption of reticulo-septo-hippocampal interconnections" (1976, p. 395).

Grossman (1976) reported that sectioning the FNX, ST, or MFB failed to mimic the deficit in acquiring the one-way active avoidance task seen in animals with amygdalar, septal, and hippocampal damage. As noted earlier, an animal should be able to encode and retrieve one strategy in a particular situation (as long as no competing responses were available) if the cortex has access to amygdala-generated emotional information during training. An alternate pathway for this amygdala information is available via a branch from the ST to the SM (see Fig. 2). The one-way deficit was reproduced by sections of the SM (which appear to be downstream from the ST branch) performed by Ross in Grossman's laboratory (Grossman, 1976).

A Functional Meta-system

Human beings differ from lower forms in that a large part of human brain development and organization occurs postnatally. The special and evolved integrative functions which distinguish homo sapiens are related to specialization of the secondary and specifically human tertiary association areas which do not reach functional

maturity until relatively late in ontogeny. The progression in species from dependence on primitive perceptions through secondary and tertiary integration is also evident in the development of brain function in human individuals ('ontogeny recapitulates phylogeny'). The primary projection areas are operational at birth; secondary association areas are programmed for function (via "learning") after birth (Penfield, 1975); the tertiary integration areas do not become fully operative until the seventh year of life (Luria, 1973a). (This developmental sequence appears to parallel Piaget's descriptions of sensory-motor, concrete operational, and formal operational stages.) During ontogeny, the lower systems in the hierarchies become subordinate to the higher levels: elementary perceptions are fit into learned schemes and, in adults, are coded into logical systems (Luria, 1973a). Inadequate development at any one level will affect functioning at higher levels.

The development in humans of manual dexterity and, later, of speech required the specialization of certain secondary and tertiary association areas. A tendency emerged for these operations to be organized in one hemisphere of the brain (Luria's law of the progressive lateralization of functions). At this point the functions of the hemispheres began to differ radically.

Both hemispheres possess advanced circuitry with the capacity for high level information processing. However, they are relatively isolated from each other and the left is genetically prepared to deal with language. The primary projection areas in the two hemispheres have identical roles, but the secondary and tertiary

association areas, responsible for an increasingly complex synthesis of incoming information, becomes specialized to perform different tasks in different ways. The mode of information processing in the two hemispheres begins to diverge as speech comes to dominate the functional organization of association areas on the left, leaving the high level integration of nonverbal sensory input to their counterparts on the right. In the course of ontogenetic development the tertiary zones within each hemisphere begin to control the work of the secondary areas, which become subordinate to them (Luria, 1973a, ch. 2). In this manner the basic perceptual processes are altered to conform to the needs of the higher centers. The secondary association areas on the left become specialized to perceive semantic data which can be coded into logical systems. The left tertiary area analyzes this input sequentially, abstracting relevant details and associating these with verbal symbols (see Nebes, 1977). The secondary areas on the right specialize in analyzing concrete structural data and relationships which are organized into complex wholes by the tertiary association area on that side.

Evidence (to be detailed below) indicates that during development these two increasingly specialized cortical information processing systems (each with its own subjacent memory, emotion, and arousal subsystems) become organized into a single functional meta-system in which the cortical components are yoked together by the limbic system. This meta-system optimizes the utilization of its complementary components in the service of producing adaptive behavior and assuring the survival of the species. Within this

meta-system the right hemisphere performs the functions of an environment "monitoring" system and the left hemisphere constitutes a problem-solving and response-generating system; the amygdalae and the left prefrontal lobe form an emotional "motivation" system; and the reticular activating system; (with their brainstem, thalamic and prefrontal lobe components) compose a cortical "mobilization" system.

While the differences between the cognitive operations performed by the left and right cerebral hemispheres may have been over-popularized little, if any, attention has been paid to the fact that the older medio-basal and subcortical structures (which subserve the processes of emotion and attention) are also bilaterally represented. It is common practice to refer to "the" limbic system when in fact the components of this system are duplicated within each half brain. It is reasonable to expect that these lateralized structures are also specialized as to function, or reflect the specialization of the neocortical mechanisms which they subserve. In the context of the functional meta-system, motivation and arousal must normally be activated by the right (monitoring) system and responded to by the left (problem-solving and response-generating) system. If this were not the case then the automatic nature of the overall system (which is guaranteed by the relative isolation of its components) might be defeated with the result that adaptive behavior would not be assured in survival situations. A basic assumption here is that mother nature would not relinquish instinct-based responding and permit self-determined behavior without firm

guarantees that the species would continue to survive. (The psychological correlates of emotion and arousal activated by the left hemisphere will be discussed in the section on psychopathology, below.)

The normal chain of events within the meta-system might be traced as follows (see Fig. 4): neuronal signals, originating in the sensory receptors, which reflect novel or potentially significant environmental stimuli excite the brainstem raphe' nuclei by way of sensory nerve collaterals. The raphe' nuclei activate the reticular formation resulting in generalized cortical arousal (orienting). (1) The right hippocampal system responds to environmental stimuli by causing the (cortical) memory traces which represent the organism's previous experience with similar stimuli to be activated; (2) if any of these memory traces contain coded emotional attributes the right amygdaloid complex is activated by them; (3) the amygdala, (a) acting via the septal area, focuses the hippocampal memory search on the significant memory trace with the secondary effect of releasing hippocampal inhibition of the reticular formation and (b) influences the reticular formation directly to release mobilizing energy and (c) relays its activation to the left amygdala via the anterior commissure; (4) left amygdala activation is then forwarded (via the dorsomedial thalamic nucleus to the left orbitofrontal cortex where it achieves conscious awareness as subjective emotional experience; (5) the dorsolateral area of the left prefrontal lobe utilizes this motivational information to formulate intentions and will attempt to resolve the

emotional experience by programming cognitive operations in the left post-central association areas to analyze the situation (aided by context information and generalized expectations obtained from the right experiential memory system in steps two and three) and formulate a behavioral response; (6) the behavioral response alters the situation, allowing the termination of motivating and mobilizing systems activity.

Evidence concerning the proposed model will be organized and presented below in terms of its relevance to the arousal, emotional, and cognitive components of the meta-system.

Lateralized Mobilization Processes

The functional meta-system model suggests that the initial identification or categorization of an environmental stimulus will normally take place in the right hemisphere which will then trigger the mobilization of the left half of the brain to deal with that stimulus. Substantial support for this postulate is provided by data from investigations utilizing different experimental approaches.

Asymmetrical reaction time to laterally presented stimuli.

Hielman and Van Den Able (1977) tested the effect of neutral warning signals (WS) presented to the left or right visual half-field on right hand reaction time (RT) to a centrally presented light. They found that a WS presented to the right hemisphere reduced RTs of the right hand more than a WS presented to the left hemisphere. Bowers and Hielman (1976) examined between-hand RT differences to a binaurally presented tone which was randomly preceded by a verbal or nonverbal WS stimulus presented visually to both hemispheres

simultaneously. They found that a nonverbal WS reduced RTs of both hands equally, no RT asymmetries occurred when the verbal WS merely forewarned the subject (simple RT condition), right hand RTs were faster than left following a verbal WS only when a response-linked decision process was required (the go/no go condition in which the WS both forewarned and dictated whether or not a response should be made). The results of these two studies suggested to the authors that

The right hemisphere may activate the left hemisphere via interhemispheric pathways, whereas the extent to which the left hemisphere can activate the right hemisphere is considerably less. Essentially, a 'one-way street' is proposed in which the right hemisphere activates the left more than the left hemisphere activates the right (i.e., asymmetric interhemispheric activation). (Bowers & Hielman, 1976, p. 7)

Altered GSR following unilateral brain injury. Hielman, Schwartz and Watson (1978) studied arousal responses in patients with left hemisphere damage (an aphasia syndrome), right hemisphere damage (with the neglect/indifference syndrome), and no brain damage, by electrically stimulating the forearm ipsilateral to the brain injury and measuring GSR from the fingers on that side. They found that the right hemisphere group showed significantly less GSR than either the left hemisphere or control groups (five of the seven right hemisphere patients had no measurable GSR at all). The left hemisphere group had an exaggerated GSR relative to the controls. These results were not attributable to differences in sensory input or lesion size. The authors concluded that patients with right hemisphere injuries and neglect have defective arousal.

They suggested that this hypoarousal might be a factor in the indifference and other mental status anomalies that are common in these patients.

Asymmetrical biochemical and electrophysiological processes.

Evidence reviewed in an earlier section delineated two separate cortical mobilization systems which co-exist in each hemisphere. A diffuse arousal system is based on the serotonergic (5-HT) neurons of the median raphe nuclei located in the core of the reticular formation. An attention focusing activation system utilizes the catecholamines NE and DA which are derived from the more laterally placed locus ceruleus and nuclei in the periaqueductal gray. The diffuse, indiscriminate arousal of cortical neurons produced by the 5-HT system results in increased stimulus reactivity and other phenomena which facilitate the primary objective of orienting processes (i.e., stimulus sampling and identification). Conversely, the focusing of attention produced by the NE-DA activation system is essential to the processes of analysis and response generation. The proposed model would suggest, therefore, that 5-HT related mobilization processes would predominate in the right hemisphere and NE/DA related processes would be more evident in the left. Gottfries, Perris, and Roos (1974) found that increased levels of the serotonin metabolite 5-hydroxyindoleacetic (5-HIAA) in the cerebrospinal fluid was significantly and positively correlated with the amplitude of auditory evoked potentials from the right, but not the left hemisphere in a group of mixed psychiatric patients. On the other hand, increased levels of the

NE/DA metabolite homovanillic acid (HVA) in the CSF was significantly and positively correlated with the amplitude of evoked potentials from the left, but not from the right hemisphere. These findings indicate that an identical stimulus triggers mobilization processes associated with orienting in the right hemisphere and with problem-solving/response-generating in the left.

Bilateral Interaction in Emotion and Cognition

The model outlined above specifies that the quality of significance is encoded along with context information in neuronal models (memories) which are stored in the neocortex. When such a model is activated by an environmental stimulus this coded information causes the amygdala to generate an emotional response which will motivate the organism to respond appropriately. This cortical-limbic system interaction was apparent in a unique experiment performed by Doty (1973) in which a macaque monkey was prepared with a unilateral amygdectomy combined with sectioning of the optic tract on the opposite side, thus blinding the hemisphere with the intact amygdala. This was followed by sectioning of all the forebrain commissures except for the posterior one-third (the splenium) of the corpus callosum. The splenium was ensnared by a ligature which was left protruding through the skull. After recovering from surgery the animal was placed in a large enclosure. When a man entered the enclosure the animal responded with normal fear and fled. However, when the commissural transection was completed (by pulling the snare) the animal's behavior was dramatically different; it became docile and would actually approach and

nuzzle the man. Prior to the completion of the neocortical disconnection the hemisphere that was blind but capable of feeling fear received adequate information from the sighted side to activate the intact amygdala and motivate the organism appropriately. However, when this blind but fearful hemisphere was isolated the animal's behavior was determined by the sighted but fearless side. (The animal responded with normal fear and aggression when touched on the trunk or limb.) The result was, in effect, a functional bilateral amygdalectomy with regard to visual stimuli (Puccetti, 1977), demonstrating that without adequate cortical input to the amygdala the organism cannot behave in an adaptive manner.

When a visual stimulus is presented tachistoscopically to one hemisphere (by way of the left or right visual half-fields) in a split-brain patient, the opposite hemisphere is "blind" with respect to that stimulus. Case P.S. differs from earlier split-brain patients in that his anterior commissure (which connects the amygdalae and temporal lobes) was left intact. The combination of these factors led to an important discovery in the course of a standard experiment with P.S.:

On the verbal command test . . . where a word was lateralized to the right hemisphere and P.S. was instructed to perform the action described by the word, his reaction to the word *kiss* proved revealing. Although the left hemisphere of this adolescent boy did not see the word, immediately after *kiss* was exposed to the mute right hemisphere, the left blurted out, "Hey, no way, no way. You've got to be kidding." When asked what it was that he was not going to do, he was unable to tell us. Later, we presented *kiss* to the left hemisphere and a similar response occurred: "No way. I'm not going to kiss you guys." However this time the speaking

half-brain knew what the word was. In both instances, the command kiss elicited an emotional reaction that was detected by the verbal system of the left hemisphere, and the overt verbal response of the left hemisphere was basically the same, regardless of whether the word was presented to the right or left half-brain. In other words, the verbal system of the left hemisphere seemed able to accurately read the emotional tone and direction of a word seen by the right hemisphere alone.' (Gazzaniga & Ledoux, 1977, p. 151)

Thus, P.S.'s left hemisphere appears to have experienced a directionally specific emotion in the absence of a cognition, and the required information must have been obtained from the right hemisphere via the AC. In this case it is not possible to differentiate whether the response was made possible by information passed between his amygdalae, or by cognitive information passed from the right temporal lobe to the left, or both. The interpretation of this phenomenon is further complicated by the fact that P.S. possessed language in his right hemisphere. The finding demonstrates, however, that the interaction of the hemispheres in emotion as proposed in the present model is tenable. The likelihood of such an interaction is supported by evidence concerning differences in the emotional responsiveness of split-brain patients and adults who have had their right hemispheres removed because of fast growing tumors.

The most surprising initial observation concerning split-brain subjects is still the most significant: there were no readily observable changes in the intelligence, behavior, or personalities of these patients following the disconnection of their cerebral hemispheres (Sperry, 1968). The model being

considered here would suggest that this is because the normal interactions between the hemispheres which involve motivation and arousal take place at a subcortical level. Sperry pointed out that the right hemisphere of these patients demonstrated "appropriate emotional reactions" but that "apparently, only the emotional effect gets across [to the left], as if the cognitive components of the process cannot be articulated through the brainstem . . . the affective component gets across to the speaking hemisphere, but not the more specific information" (1968, p. 732).

The proposed model specifies further that the right hemisphere in humans specializes in analyzing and recording experiential data and thus becomes the repository of the reinforcement history of the individual. The emotional responsiveness and behavior of adults whose right hemispheres were removed (because they had been invaded by life-threatening, fast growing tumors) is markedly different from the split-brain patient. Although normal intelligence is generally retained, such people show a lessened capacity for adaptability (Glees, 1961) and "suffered a loss in terms of personality values . . . defects in judgement and . . . impairment in insight, in emotional control, in initiative, and in perseverance" (Gardner, Karnosh, McClure & Gardner, 1955, pp. 500-501). These individuals, whose left hemisphere was deprived not only of sensory and cognitive information from the right (as was the case with cerebral commissurotomy patients), but also of that hemisphere's motivational and mobilizing inputs, show a clear pattern of deficits: their affect tends to be labile, inappropriate, and poorly modulated;

they have difficulty sustaining mental activity; they become ego-centric, shallow, and seemingly unaware of the social consequences of their behavior (Gardner, 1933; Rowe, 1937; Bell & Karnosh, 1949; Mensh, Schwartz, Matarazzo & Matarazzo, 1952; Gardner et al., 1955; Austin & Grant, 1962; Bruell & Albee, 1962). It may be deduced from the above that normal, adaptive, responsiveness to the environment depends on the products of right hemisphere processes. The fact that the emotional impact of a situation is available to the left hemisphere in split-brain patients but not in right hemispherectomy patients indicates that the right cerebral hemisphere in humans is responsible for making determinations regarding the significance of environmental stimuli. The contrast between the cerebral disconnection and right hemispherectomy syndromes further suggests that relatively normal emotional responsiveness, judgement, and adaptability can be maintained as long as the motivating and mobilizing products of the right hemisphere's cognitive operations can be transmitted to the left (i.e., can activate the left amygdala and ARAS). In the absence of the right hemisphere's modulating input the left hemisphere is subject to erratic and inappropriate emotional experience because the neocortex on that side is not adequately prepared to mediate these processes.

Patients with lesions in their left cerebral hemispheres typically have a catastrophic/depressive reaction while those with right hemisphere damage show a characteristic indifferent/euphoric response (e.g., Gionotti, 1972a). Transient, but similar emotional reactions are commonly seen during recovery from unilateral

hemisphere anesthetization using the Wada technique (e.g., Perris, Rosadini & Rossi, 1961) and have been reported after unilateral ECT (Deglin & Nikolaenko, 1975). Such findings have prompted speculation that each hemisphere tends toward a different emotional state.

The fundamental problem with the lateralized emotional valance theory is the fact that the actual direction of the valance cannot be specified. Tucker (1981) notes that the phenomena observed following the unilateral loss of cortical function might result from the disinhibition of the emotional tendency of the opposite hemisphere or from the release of subcortical processes on the same side.

Dimond, Farrington, and Johnson (1976) reported experimental evidence suggesting that the right hemisphere has a negative valance. They presented three short films to normal subjects' left or right visual half-fields (using a special arrangement of spectacles and contact lenses) and to free-viewing controls. The right hemisphere group rated the films as significantly more unpleasant and horrific than did the left hemisphere and control groups (who did not differ from each other). Dimond et al., concluded that the right hemisphere tends toward a negative emotional appraisal of incoming stimuli similar to the "characteristic perception of the depressed patient" (p. 691). This finding would seem to support the contralateral disinhibition interpretation of the emotional phenomena seen after unilateral brain injury. However, the contralateral disinhibition notion is discredited by

the fact that the emotional responses seen with unilateral hemisphere anesthetization occur only as the effects of the anesthetic are clearing: they should be most pronounced when the contralateral hemisphere was completely incapacitated (see Tucker, 1981).

The indifference/euphoric reaction seen after right hemisphere injury is often accompanied by neglect for the left half of the body and for the left extrapersonal space (Gionotti, 1972b). This neglect syndrome is usually associated with damage to the right IPL, although it has been reported after lesions of the right frontal lobe (Hielman and Valenstein, 1972) which presumably programs the operations of the right post-central areas. Hielman and Valenstein note that the mechanism of neglect remains unknown but observe that:

The inability of sensory stimuli to excite or alert an organism (neglect) cannot be completely explained by defect in sensory synthesis. The lesions that produce neglect must also interfere with centrifugal or descending pathways that normally would permit integrated sensory stimuli to excite or alert the organism. (1972, p. 663)

These authors suggest that neglect following parietal lobe lesions may result from disconnection between sensory association areas and the limbic system. What is most puzzling, and perhaps most significant, is the fact that neglect is rarely, if ever, seen following left hemisphere lesions.

The puzzles of lateralized emotional valance and unilateral neglect resolve themselves if the basic premises of the proposed functional meta-system hypothesis are accepted. This model suggests that the primary role of the amygdala is to generate

emotional signals which motivate the organism to respond appropriately in life or death situations (e.g., fight or flight). These signals must be transmitted via the left amygdala to the left frontal lobe before they can achieve conscious status. The subjective experiences which accompany these "primitive" emotional states are intrinsically negative, and must be in order to insure a prompt and vigorous response. The task of evaluating the significance of environmental stimuli ("monitoring") is relegated to the right hemisphere in humans, the left being occupied with language functions which require an incompatible mode of information processing. If the right hemisphere is damaged and the right amygdala receives little or no information, then no motivating emotional signal is generated to be passed on to the left side. In the absence of these signals the conscious left hemisphere is indifferent to the stimuli it perceives. If the cortex is mobilized in the absence of motivational inputs the resulting subjective state might be characterized as euphoria. Conversely, if a damaged left hemisphere is receiving emotional input from a normal (or disinhibited) right hemisphere, and the damage diminishes the left side's ability to resolve or cope with such input, the resulting experience might be characterized as catastrophic. In the case of damage to the right hemisphere's highest, and final, level of information processing (the IPL), the left would not only fail to receive emotional/alerting signals but would be deprived of processed sensory data about the left half of the body and space as well; from the left hemisphere's point of view these stimuli would cease to exist.

Springer and Deutch (1981) suggested that the left hemisphere "assumes that what it sees encompasses everything there is" (p. 176). This interpretation is supported by the fact that the speaking left hemisphere of split-brain subjects is unaware of having lost half of its sensory fields (Gazzaniga, 1970). Similarly, the subjects in the experiment reported by Dimond et al. (1976), who viewed films presented to only one hemisphere, were not aware that they were blind in one visual field. In addition, they experienced the stimuli as "centered" when in reality it was presented from the left or right of the midline. Finally, it is worth noting in this context that Korsakoff's psychosis (in which the patient is unable to gain access to recent memory traces) is commonly referred to as the "amnesic-confabulatory syndrome." The Korsakoff patient's speaking left hemisphere produces false accounts when memory fails to provide the facts. This material "is presented without awareness of its distortions or of its inappropriateness, and . . . is motivated in no other way than factual information based on genuine data" (Talland, 1965, p. 50). In short, when deprived of expected memory data, the left hemisphere believes that what it thinks is true. Considerable evidence of confabulation by the isolated left hemisphere in split-brain patients was reported by Sperry (1974).

Mental Health and Psychopathology

The model developed in the preceding sections defines the basic functional elements of the personality structure. It remains to describe the ways in which these interact to produce mental health and psychopathology.

According to the model normal, adaptive functioning requires that the problem-solving/response-generating system receive adequate information from the monitoring, mobilizing and motivating systems. Mental health would require, and result from, the integrated functioning of these basic personality elements. Conscious left hemisphere processes must be mobilized appropriately by emotional experience and "channelized" by generalized expectations which are congruent with reality (cf., Kelly, 1963). Such integrated functioning was implicit in Rogers (1963) description of the "fully functioning person":

This person would be open to his experience . . . every stimulus, whether originating within the organism or in the environment, would be freely relayed through the nervous system without being distorted by a defensive mechanism . . . the self and personality would emerge from experience, rather than experience being translated or twisted to fit a preconceived self-structure . . . since he would be open to his experience . . . this person would find his organism a trustworthy means of arriving at the most satisfying behavior in each existential situation. (1963, pp. 18-20)

Any process that interfered with the operation of an individual element, or prevented adequate interaction among them, would diminish the adaptability of the organism. The system is vulnerable to interference at several levels.

The model suggests that, at a cognitive level, generalized expectations (GEs) are the most potent influence on behavior. These significant experiential memories are assembled and stored in the right half of the neocortex and are accessed by the hippocampal system lateralized in that hemisphere. Such GEs are here defined as

experientially-based alterations in the disposition of the organism relative to a stimulus object, situation, or event. The cognitive information contained in the GE can only pass to the left hemisphere over the neocortical commissures. This exchange permits the verbal system to symbolize its reinforcement history in a given situation. It is possible that the more facile mechanisms in the left hemisphere might be conditioned to somehow prevent this exchange of information to avoid the evocation of psychological pain. In this case, the individual would experience the arousal and emotion appropriate to the stimulus but remain ignorant of its nature, and consequently, impotent in his or her efforts to resolve the subjective experience.

At least two separate mobilizing systems co-exist within each half of the brain: a serotonergic system produces indiscriminant cortical arousal which facilitates the functioning of the monitoring system in the right hemisphere; a dopaminergic activation and attention focusing system is essential to the cognitive operations of the left hemisphere's problem-solving/response-generating system. Any process which altered the balance between these two systems (within or between hemispheres) would disrupt normal functioning. The biochemical mechanisms which form the neural substrata of the motivating and mobilizing systems are modulated by descending influences from the prefrontal lobes (via the amygdalae) and from the temporal lobes (via the hippocampi). The normal functioning of these modulating pathways might thus be subverted by conditioning processes (in the interest of "defending the ego") at the expense of normal, integrated functioning. In the absence of integrated

functioning the system which has greater access to the motivating and mobilizing system would have the greatest impact on cognitive and behavioral responding. This conclusion is perhaps best exemplified in the psychological sequelae of unilateral temporal lobe epilepsy.

The Psychopathological Correlates of Unilateral Temporal Lobe Epilepsy

In all members of the phylum, biologically important experiences elicit an emotional response which facilitates the learning of biologically important behavior (Campbell, 1974). Destruction of the amygdala, or disconnection of the amygdala from the sensory cortices, results in the dissociation of affective qualities from sensory stimuli (e.g., Kluver & Bucy, 1938). Sensory-limbic association depends on a neural pathway which extends to the amygdala via the ventral temporal cortex (Bear, 1979).

Patients with temporal lobe epilepsy often show progressive personality changes which culminate in patterns which are indistinguishable from certain psychodiagnostic entities. Bear (1979) reviewed evidence suggesting that these changes are produced by chronic over-stimulation of the amygdala. In contrast to the consequences of temporo-limbic disconnection, he postulated that the alternations in behavior, emotion, and thought observed in this disease stem from a process of temporo-limbic hyperconnection: a "progressive overinvestment of perception and thought with affective significance" (p. 359).

Bear and Fedio (1977) compared the self-reported and observer ratings of personality traits in patients with left and right temporal lobe epileptic foci. Factor analysis revealed two factors which

differentiated between the two groups. On an emotive-ideative dimension, patients with right temporal foci were distinguished by externally demonstrated affect while the left group was characterized by ideational/ruminative traits. On a normal-severe dimension the left group of patients reported more severity compared to the right and endorsed more socially disapproved traits (e.g., paranoia, aggression, dependence) but the rater evaluated the right group as more severely disturbed. Bear (1979) observed that both groups displayed a characteristic high intensity of affect but differed in verbal awareness of the emotions. The major difference between the groups was in the way they interpreted and reported their abnormal affective experience. Bear suggested that "strong affect expressed as mood excess differs from cognitive elaboration, often verbal or logical, of specific relationships between stimuli and affect" (1979, p. 370). This difference might account for the fact that the right hemisphere epileptic foci have been associated with mood-affective disorders and left foci with cognitive-paranoid psychosis (Flor-Henry, 1974). Bear and Fedio (1977) speculated about the ways in which a patient might interpret the enhanced affective associations to previously neutral events or concepts which result from chronic temporo-limbic hyperconnection:

Experiencing objects and events shot through with affective coloration engenders a mystically religious world view if a patient's immediate actions and thoughts are so cathected, the result is an augmented sense of personal destiny. A felt significance behind events that others dismiss constitutes a seed bed for paranoia or may confirm the feeling that the patient is a passive pawn in the hands of powerful forces that structure the world. Feeling fervently about rules and laws

may lead to action in which the patient "takes the law into his own hands." Sensing emotional importance in even the smallest acts, he performs these ritualistically and repetitively. Since details bear the imprimatur of affective significance, they may be mentioned in lengthy, circumstantial speech or writing. (p. 465)

Discussion: Hyper- and Hypo-dominance Spectrum Disorders

The proposed functional meta-system model specifies that, in survival situations, emotion and arousal are normally triggered by the right ("monitoring") system and are resolved by the left ("problem-solving") system. The right memory system also provides appropriate context information and generalized expectations (via the cerebral commissures) to assist in this process. When the verbal left hemisphere initiates limbic system processes directly (e.g., by triggering its own amygdala) there would be a tendency toward a vicious circle: the increased attentional/emotional activity would exacerbate the focus on the initiating cognitive theme (rather than eliciting an objective response to environmental requirements). In normal circumstances this reverberating unilateral process might account for mood (the maintenance of affective tone in the absence of external stimuli). If abnormally exacerbated, the process might produce the rigidified cognitive phenomena associated with various pathological syndromes (e.g., anxiety, depression, paranoia, obsessions). In addition, the overactive verbal system would systematically initiate searches in the contralateral memory system for experiential data which were congruent with its abnormal cognitive state. Finally, memories encoded with "artificially" induced emotional significance would, by definition, tend to deviate from reality.

Cognitive activity in the right hemisphere is limited by its inability to manipulate time. The right half of the brain is context-bound, both internally and externally; its products are reflexive, not considered. While the right hemisphere is responsible for mediating the external expression of immediate affect the appreciation of subjective emotional experience is a left-brain function. Right brain activities are seen here as ancillary processes which are utilized by the left. Contrary to recent theories which tend to conceptualize psychopathology as emerging from the disruption of a balance between right and left brain functions (e.g., Bogan, 1969b; Flor-Henry, 1979; Tucker, 1981) the present model emphasizes the need for integration of the influences which converge on the left hemisphere. Any process which interfered with the integrated functioning of the meta-system would be, by definition, pathological. A process which culminated in the relative overactivation of the left hemisphere would diminish the right hemisphere's modulation of behavior and, conversely the right hemisphere's contribution would be exaggerated when activation of the left was reduced or disrupted. Such processes would be exacerbated by the effects of reciprocal transcallosal inhibition (Flor-Henry, 1979). Since considered, "self-determined" responding is coordinated by the left hemisphere such processes would lead to pathological conditions of hyper- and hypo-dominance, respectively.

In the following paragraphs standard psychodiagnostic entities will be related to neurological indices which reflect the operation and interaction of elements within the proposed functional meta-system.

the evidence suggests that these entities may be divided into hyper- and hypo-dominance spectrum disorders. Such a grouping should have important theoretical implications for the treatment of these disorders.

Schizophrenia and the Affective Disorders

The neurological correlates of schizophrenia and the affective disorders have been reviewed by Tucker (1981) and Flor-Henry (1979). The evidence suggests that these major disorders involve a severe disruption of intrahemispheric functioning in addition to the disturbances in interhemispheric information flow which is seen here as contributing to neurotic and characterological illnesses.

The finding, noted earlier, that left temporal lobe epilepsy often evolves to a schizophreniform pattern of symptomology is paralleled by evidence of left hemisphere EEG abnormalities in schizophrenia (see Tucker, 1981; Flor-Henry, 1979). The evidence suggests that this abnormal cortical mobilization is mediated by the dopaminergic activation system. Disruptive overactivation of the left hemisphere, and right-ear deficiencies in temporal discrimination tasks observed in schizophrenics were both normalized following administration of chlorpromazine (Serafetinides, 1973; Gruzelier & Hammond, 1976), a drug which blocks dopamine receptors.

Bruder and Yozawitz (1979) reported that patients with affective disorders showed left-ear deficiency on dichotic listening tasks which were correlated with the level of symptomology, indicating right hemisphere dysfunction. This is consistent with findings that unilateral right ECT and bilateral ECT were superior to left

ECT in relieving the symptoms of depression (haliday, Davidson & Brown, 1968; Cronin, Bodly & Potts, 1970).

While the dopaminergic activation system appears to predominate the mobilization of the left hemisphere, the serotonergic arousal system seems to be more important in modulating the right hemisphere's activity (see Gottfrieds, Perris & Roos, 1974). In their pharmacological investigation, Mandell and Knapp (1979) found that lithium treatment significantly reduced serotonin hemispheric asymmetry. They hypothesized that the phenomenon of mood may be an emergent property of asymmetrical serotonin regulation, and suggested that varying degrees of serotonergic asymmetry accounted for the phase being manic or depressive in bipolar affective disorders. (They did not speculate on the direction of the asymmetry.)

Flor-Henry (1979) reported on a complex analysis of EEG data taken from bipolar patients engaged in performing verbal and spatial tasks (WAIS Vocabulary and Block Design subtests) and in neutral conditions. He found abnormally high right parietal activity and variability in depression which became bilateral in mania and schizoaffective disorders. He also noted that, during spatial tasks, depressives showed an increase in left temporal activity (versus neutral conditions); they also showed an increase in right parietal activity during verbal tasks. He suggested that these changes indicated that complex shifts of lateralized hemispheric specialization were taking place. If this is the case, it is tempting to speculate that such shifts might be caused by a reversal of the normal inter- and intrahemispheric pattern of interaction between the DA and 5-HT mobilization systems.

Anxiety Disorders, Obsessive-Compulsive Illness, and Paranoia

On the WAIS, a verbal I.Q. that is significantly higher than performance I.Q. is especially characteristic of patients with anxiety neurosis (see evidence summarized by Ogden, 1967). This relationship indicates a relative predominance of left hemispheric processes in this disorder. Tucker and his colleagues (1978) reported two experiments which linked anxiety with left hemisphere overactivation and dysfunction. Subjects reporting high anxiety showed performance decrements on tasks lateralized (via the visual half-fields) to the left, but not the right, hemisphere. High trait anxiety was also associated with a right-ear attentional bias and a low incidence of left lateral eye movements (Tucker, Antes, Stenslie & Barnhardt, 1978).

Anxiety patients show lower than normal CNV amplitude. The CNV develops slowly and irregularly in acute anxiety states, extinguishes rapidly during deconditioning, and reappears slowly, if at all, on reconditioning trials (Cohen, 1974). Since the CNV has been related to the dopamine-mediated activation system, the elevated levels of psychological activity and reduced cognitive efficiency seen in anxiety states appears to be related to excessive serotonin-mediated arousal processes in the left hemisphere. By contrast, obsessive-compulsive subjects have an exaggerated CNV amplitude which shows slow resolution, less decrement with partial reinforcement, and fails to habituate (Cohen, 1974). Thus, the excessive (verbal) cognitive activity which is characteristic in these individuals seems to be related to overactivation of the dopamine-mediated

activation system. (The association between NE-mediated mobilization processes involving the locus ceruleus and cingulate cortex and the "hyper-indexing" of memories in obsessive-compulsive illness was noted in an earlier section.)

Amphetamine increases the amount of dopamine available at synapses. In animals, increasing amounts of dopamine activation results in a decrease in the ranges of behaviors emitted and an increase in the frequency of a few behaviors, leading to stereotyped motor sequences at high doses (Iverson, 1977). In humans, chronic amphetamine abuse has been reported to result in stereotyped repetitive behaviors, increased attention to detail, compulsive disassembly of objects, ruminative preoccupation with intellectual ideation, and features of hypervigilance difficult to distinguish from paranoid schizophrenia (Ellinwood, 1967).

Witkin (1965) developed the concept of a field-dependence-independence dimension in perception. In the field-dependent mode, perception is dominated by the overall organization of the field, the parts of which are experienced as fused. In field-independent perceiving, parts of the field are experienced as discrete from organized background (cf., perceptual augmenting and reducing).

Field-dependence and independence were dramatically related to right and left hemisphere functioning, respectively, in an experiment utilizing unilateral ECT as the independent variable and rod-and-frame test scores as the dependent variables. Twenty-four subjects were administered the rod-and-frame test shortly after admission to the clinic and were randomly assigned to receive right or left ECT

(for the treatment of depression) within 48 hours. A second rod-and-frame test was administered five hours after the treatment. Twelve subjects whose first treatment was rescheduled for non-clinical reasons served as controls and were retested five hours after the missed first appointment. The results were highly significant; all twelve left ECT patients showed more field-dependence on the second test; all twelve right ECT patients showed less field dependence; the controls showed little or no change (Cohen, Berent & Silverman, 1973).

Witkin (1965) relates the field-dependence-independence perceptual dimension to a cognitive differentiation dimension: the person who is field-dependent also does less well at "solving problems which require isolating essential elements from the context in which they are presented and using them in different contexts" (1965, p. 319). The cognitive differentiation dimension is manifest in a global/diffuse versus an articulated cognitive style. The field-dependent/global style has been associated with hysterical neurosis (Zukmann, 1957), character disorders, somatization, alcoholism, and patients whose primary symptom is affective discharge (see the review by Witkin, 1965). A field independent/articulated personality style has been associated with paranoia (Janucci, 1964; Powell, 1964) and obsessive-compulsive disorders (Zukmann, 1957).

Sociopathy and Hysteria

The absence of anxiety and the inability to learn from experience are pathonomic in sociopathy. In contrast to anxiety neurotics,

"the most outstanding single feature of the sociopath's WAIS test profile is his systematic high scores on the performance as compared to the verbal part of the scale" (Wechsler, 1958, p. 176). The same pattern was found to be characteristic of hysterics (Schafer, 1948). These relationships indicate a relative predominance of right hemisphere processes in these disorders. The correlation between low levels of left hemisphere functioning and low anxiety is also striking. The PIQ greater than VIQ WAIS pattern has been associated with "acting out" tendencies (Ogden, 1967). Silverman, Buchsbaum, and Stierlin (1973) found that acting out adolescents showed evoked potential augmenting. Augmenting has also been associated with high scores on a sensation seeking scale (Zuckerman, 1974) and with alcoholism (Knorrning, 1979; Coger, 1976), traits which are common in sociopathy and hysteria (see Balis, 1978).

Smokler and Shevrin (1979) used lateral eye movements as an index of relative hemispheric activation in obsessive-compulsive and hysterical personality style subjects (designated by modified standard tests). They found significantly more left-looking among the hysterical subjects indicating increased right hemisphere activation in this disorder. They suggested that these personality styles may be related to "predominant use of one or the other hemisphere" (p. 952).

The dissociative reactions seen in hysterical neurosis (amnesia, depersonalization, fugue, multiple personality) are indicative of a failure to encode or access memories in the verbal system (cf., Gazzaniga, 1977). The finding that hysterical conversion symptoms

tend to be lateralized to the left half of the body (Galín, Diamond & Braff, 1977) suggests a right hemisphere involvement in these phenomena. The hysteric's characteristic indifference to these manifestations is similar to that seen with right cortical lesions, which has been interpreted here as the failure of the right cortex to trigger subcortical motivation and mobilization processes.

In sociopathic patients the CNV is absent or develops only very low voltage (Cohen, 1974). The tendency for sociopaths and hysterics to be field-dependent with a global/diffuse cognitive style was noted earlier. This is consistent with the poorly articulated self-concepts and value systems generally seen in these personality types. The egocentricity and impulsiveness which characterize these people typifies the reflexive, context-bound functioning of the right hemisphere. All of these trends indicate that the left hemisphere is less involved in the organization of behavior in these individuals.

Neurotic symptoms were found to be common following right temporal lobectomy for epilepsy, while psychopathic disorders were more frequent following this operation on the left side (Taylor, 1972). These findings provide significant support for the present functional meta-system model which postulates that normal emotional responsiveness depends on a motivation system pathway which extends from the right amygdala (which is activated by the monitoring system) to the left amygdala and on to the left prefrontal lobe

where the motivational signals are experienced as subjective emotion. When this pathway is disrupted (by excision of the left temporal components) emotional responsiveness is lost. When the right temporal components are removed, motivational signals are generated only on the left side and neurotic symptoms result. Failure of the right hemisphere's monitoring system to activate the right limbic system results in the failure to mobilize the left hemisphere (so right processes have increased influence on behavior) and lack of motivation signals to guide left hemisphere processes.

CHAPTER III METHOD

This study was designed to affirm or disaffirm the consequents of the proposed theoretical model of personality function and psychopathology and to demonstrate a confluence of psychological and neurological observations. Specifically, the investigation attempted to ascertain whether groups of adult psychiatric patients classified according to the constructs of the proposed model as suffering from hypo- or hyper-dominance spectrum disorders differed significantly from each other on a ratio of test scores that have been demonstrated to be sensitive to damage to the left and right cerebral hemispheres, respectively, without differing significantly in overall performance on the instruments.

Both spectrum disorders are personality disturbances defined by chronically diminished social performance and/or dysfunctional behavior patterns without a clear precipitating factor. Both exclude gross impairments of perception, orientation or memory. Hyper-dominance spectrum disorders are defined as disorders in which the primary symptoms are manifested intrapsychically and/or are characterized by a central tendency to maladaptive overutilization of formal thought processes. Hypo-dominance spectrum disorders are defined as disorders in which the primary symptoms are manifested extrapsychically and by a central tendency to maladaptive underutilization of formal thought processes. DSM III diagnostic categories which meet these criteria are listed in Appendix A.

Subjects

A total of 42 adult psychiatric patients served as subjects in this study. Twenty outpatients were taken from an urban community mental health center and three rural satellite clinics. Twenty-two inpatients were taken from a state forensic hospital. Subjects were assigned to the hyper- or hypo-dominant groups by DSM III Axis I and II diagnoses (see Appendix A).

The hypo-dominant group (N=22) consisted of 13 males and nine females. Eighteen were right-handed, one left-handed and three ambidextrous by self-report. The mean age was 30.45 years with a standard deviation of 12.14 years. The diagnoses within this group included 14 antisocial personality disorder (eleven of whom were classified as mentally disordered sex offenders undergoing inpatient treatment at the state forensic hospital); three histrionic personality disorder; two dependent personality disorder; one avoidant personality disorder; one narcissistic personality disorder; one psychogenic pain disorder.

The hyper-dominant group (N=20) consisted of 14 males and six females. Ten were right-handed, one left-handed and three ambidextrous by self-report. The mean age was 42.65 years with a standard deviation of 13.73 years. The diagnoses within this group included 11 schizophrenia, paranoid types (all of whom were adjudicated incompetent to stand trial and undergoing inpatient treatment at the state forensic hospital); two generalized anxiety disorder; two compulsive personality disorder; three dysthymic disorder; one simple phobia; one agoraphobia with panic attacks.

All subjects were selected by diagnosis and were asked to participate by their primary therapist. Each subject read an informed consent statement (Appendix B) before being tested.

Instruments

The dependent measures in this study were scores on the Street (1931) Gestalt Completion Test; the WAIS-R Object Assembly, Similarities and Information Subtests (Wechsler, 1981); and the Mini-Mult, a 71 item abbreviated form of the MMPI (Kincannon, 1968). The Street Test and the Object Assembly Subtest have both been shown to be differentially sensitive to right hemisphere cognitive processes and right hemisphere damage impairs performance on these tests (Bogan, Dezure, Ten Houten & March, 1972; Direnzi & Spinnler, 1966; Ogden, 1967; Matarazzo, 1972; Rapaport, 1951; Black, 1974). The Similarities and Information Subtests of the WAIS-R have been shown to be differentially sensitive to the left hemisphere cognitive processes and left hemisphere damage impairs performance on these tests (Bogan et al., 1972; Ogden, 1967; Matarazzo, 1972; Rapaport, 1951). Bogan et al. (1972) demonstrated that patients with partial sectioning to the cerebral commissure show higher scores on the Street Test and higher Street/Similarity ratios than patients with complete sectioning of the commissures. This was interpreted by the authors as indicating that the Street Test normally required right hemisphere processing.

Scales 3 and 4 from the MMPI were selected as representing symptoms that are characteristic of the hypothesized hypo-dominance spectrum disorder. High scorers on Scale 3 (hysteria) show a

"general denial of physical health . . . denial of psychological or emotional problems and of discomfort in social situations. . . . They react to stress by developing physical symptoms . . . [and] are not likely to report anxiety, tension or depression" (Graham, 1977, pp. 38-39). High scorers on Scale 4 (psychopathic deviate) show "absence of satisfaction with life, family problems, delinquency, sexual problems, and difficulties with authorities" (Graham, 1977, p. 41). Scales 5 and 7 were selected as representing symptoms that are characteristic of hypothesized hyper-dominance spectrum disorders. The high scorers on Scale 6 (paranoia) show paranoid symptoms. Scale 7 (psychasthenia) is a good index of psychological turmoil, including excessive doubts, anxiety, compulsions and obsessions, unreasonable fears, and tension (Graham, 1977). Graham concluded that the Mini-Mult is "useful for comparing groups, particularly if they are psychiatric patients . . ." (1977, p. 219).

Procedure

Demographic information and diagnostic data were taken from the subjects' clinical records. No identifying information was recorded. The Mini-Mult was administered by the subjects' primary therapist. Subjects were tested by the author before or after their regularly scheduled therapy session. Street Test, Similarities, Object Assembly, and Information Subtests were administered in that order. Diagnostic data, demographic information and test responses were entered on a subject data form. The WAIS-R subtests and the Mini-Mult were scored by the author using standard scoring criteria (Wechsler, 1981; Kincannon, 1968). The Street Test as originally standardized (Street, 1931) includes a number of antiquated items and the

scoring criteria for two items were altered for this study. (The complete scoring criteria used are presented in Appendix C.)

Hypotheses

The following hypotheses were generated:

1. The ratio of the sum of the raw scores on the Street Gestalt Completion Test and the WAIS-R Object Assembly Subtest to the QAIS-R Similarities and Information Subtests (Street + Object Assembly/Similarities + Information) will differ between groups with the hyper-dominant group showing relatively better performance on the Similarities and Information Tests and the hypo-dominant group showing relatively better performance on the Street and Object Assembly Tests.
2. The sum of the standardized scores (z-scores) on all the tests (Street + Object Assembly + Similarities + Information) will not differ between the groups.
3. The ratio of the sum of the MMPI T-scores for scales three and four to the sum of the T-scores for scales six and seven ($3T + 4T/6T + 7T$) will differ significantly between groups with the hyper-dominant group showing relatively higher scores on scales six and seven and the hypo-dominant groups showing relatively higher scores on scales three and four.

CHAPTER IV RESULTS

Left versus Right Hemisphere Cognitive Functioning Between Groups

Hypothesis 1 stated that the hyper- and hypo-dominant spectrum disorders would differ on the ratio of scores on tests that have been demonstrated to be sensitive to left and right hemisphere cognitive functioning. Specifically, it was hypothesized that the hyper-dominant group would show relatively better performance on the Similarities and Information WAIS-R Subtests and the hypo-dominant group would show relatively better performance on the Street Test and the WAIS-R Object Assembly Subtest. The mean ratio (Street + Object Assembly/Similarities + Information) for the hyper-dominant group was $\bar{x} = 1.15$ (SD = 0.42) while the mean ratio for the hypo-dominant group was $\bar{x} = 1.91$ (SD = 0.84), indicating that the groups differed in the predicted directions. A student's t-test for independent samples (Robson, 1973) performed on these means revealed that the differences between groups was significant ($t = 3.46_{40}$, $p < 0.001$, one-tailed). It was concluded that psychiatric inpatients and outpatients assigned to the hyper-dominant spectrum disorder group performed better on tests sensitive to left hemisphere cognitive functioning relative to tests sensitive to right cognitive functioning; their ratio scores

differed significantly ($p < 0.001$) from patients assigned to the hypo-dominant group, who scored relatively better on tests sensitive sensitive to right, relative to left, ehmisphere cognitive functioning, as predicted by the proposed model.

Overall Performance on the Tests Sensitive to Right versus Left Hemisphere Cognitive Functioning

Hypothesis 2 suggested that any differences discovered in the test of Hypothesis 1 would be due only to differences in the ratios between groups and not to any other pattern of overall performance on the tests (e.g., intelligence). To test this hypothesis, standardized scores (z-scores based on the total n) were derived for each subject's individual test scores (following Robson, 1973) and added togehter for each group (Street + Object Assembly + Similarities + Information). The mean z-score was $\bar{x} = 0.09$ for the hypo-dominant group and $\bar{x} = -0.04$ for the hyper-dominant group. A student's t-test for independent samples (Robson, 1973) performing on these means revealed no significant differences between groups ($t = 0.87_{166}$, $p < 0.4$, two-tailed, N.S.). It was concluded that there were no significant differences on overall test performance between groups and that the differences in ratios found in the test of Hypothesis 1 were not due to any factor (e.g., intelligence) other than the one being tested.

Differences in MMPI Scores

Hypothesis 3 amounted to a verification of the subjects' diagnoses and provided an additional test of the ability of the proposed model to predict membership in diagnostic categories based on an assessment of personality traits. Specifically, it was hypothesized

on an assessment of personality traits. Specifically, it was hypothesized that the hyper-dominant group would score relatively higher on MMPI clinical scales (6 and 7) which indicate symptoms that are manifested intrapsychically and suggest a central tendency to chronic and maladaptive overutilization of formal thought processes while the hypo-dominant group would score relatively higher on MMPI clinical scales (3 and 4) which indicate symptoms that are magnified extrapsychically and suggest a chronic and maladaptive underutilization of formal thought processes. The mean ratio ($3T + 4T/6T = 7T$) for the hyper-dominant group was $\bar{x} = 1.01$ ($SD = 0.12$), while the mean ratio for the hypo-dominant group was $\bar{x} = 1.12$ ($SD = 0.14$), indicating that the groups differed in the predicted directions. A student's t-test for independent samples (Robson, 1973) performed on these means revealed that the difference between groups was highly significant ($t = 2.75_{40}$, $p < 0.005$, one-tailed). It was concluded that psychiatric inpatients and outpatients assigned to the hyper-dominant spectrum disorder group scored relatively higher on MMPI clinical scales which indicate symptoms that are manifested intrapsychically and suggest a chronic and maladaptive overutilization of formal thought processes; their ratios differed significantly from those of patients assigned to the hypo-dominant group, who scored relatively higher on MMPI clinical scales which indicate symptoms that are manifested extrapsychically and suggest a chronic underutilization of formal thought processes, as predicted by the proposed model.

Age

The mean age in the hyper-dominant group was $\bar{x} = 42.65$ years (SD = 13.73 years). The mean age in the hypo-dominant group was $\bar{x} = 30.45$ years (SD = 12.14 years). A student's t-test performed on these means revealed significant differences between groups ($t = 2.12_{40}$, $p < 0.05$, two-tailed).

CHAPTER V DISCUSSION

This study was an attempt to affirm or disaffirm certain central consequents of the proposed model of personality function and psychopathology. With this type of design a failure to support the hypotheses is unequivocal: the theory cannot be true. If the consequences are clearly verified there is some indication that the theory may be true. All of the hypotheses in this experiment were supported at high levels of statistical significance. It was concluded that the proposed theoretical model of personality function and psychopathology is tenable and may provide useful operational definitions for the applied psychologist.

The value of an experimental test of a theory is determined, in large part, by the strength of the chain of reasoning between the hypotheses and the data. In this study that connection is relatively straightforward. Based on the functional meta-system model it was postulated that the manifestations of personality dysfunction (i.e., psychopathology) will be determined by the properties of the cerebral hemisphere with greater access to the limbic system. It was proposed, therefore, that there are two major subtypes of psychopathology. Since the functional impact of disturbances within the meta-system is thought to be experienced in the left cerebral hemisphere (which alone possesses the requisites for self-awareness

and considered response generation), it is convenient to express these two forms of pathology in terms of hyper- or hypo-dominance. Any given pathological syndrome will reflect both the point of disturbance within the meta-system and the attempts of the rest of the system to compensate, but most may be classified as hyper- or hypo-dominance spectrum disorders with the primary symptoms manifesting themselves either intra- or extrapsychically, respectively.

A major consequence of hyper- or hypo-dominance is the availability of right hemisphere cognitive products to the left for utilization in response generation. The validity of the instruments used as dependent measures in this study is well established and their sensitivity to lateralized cognitive processes has been adequately documented. The relationship between these indices of lateralized brain functions and personality traits (as measured by the relevant clinical scales of the MMPI) was clearly demonstrated and congruent with the predictions of the theory. The agreement between the MMPI data and the diagnoses used to assign subjects to the experimental groups also enhances the value of the results.

A number of other factors contribute to the validity and generalizability of the results in this study. Considerable design risks were undertaken in that variables were introduced which would have invalidated the results had they not conformed to predictions. The assignment of mentally disordered sex offenders exclusively to the hypo-dominant group and general psychiatric forensic inpatients to only the hyper-dominant groups could not have been justified if the two experimental groups had differed in overall performance on the

cognitive function measures. Given the outcome, however, the inclusion of these two inpatient populations greatly enhances generalizability. The absence of overall between-group differences on these dependent measures also effectively rules out extraneous factors (e.g., I.Q.) in the production of the results and dramatically emphasizes the importance of the predicted left-right ratio variable.

Since the hyper-dominant group was significantly older ($p < .05$) than the hypo-dominant group, it could be argued that age accounted for the observed differences between groups. It is well established, however, that hypo-dominant type symptoms tend to diminish with aging (e. g., See Balis, ch. 4) and the observed difference is believed to reflect the normal distribution of symptoms in the population.

An important limitation in this study is the fact that only cognitive factors and personality traits were observed. One could reject the functional-meta-system theory and interpret the results in terms of Bogan's (1969c) "hemisphericity"/"dual mind" notion. In this case the demonstrated correlation between lateralized cognitive functions and personality traits would be seen as manifestations of "mind left" versus "mind right." This alternative is discredited, however, by the documented differences between split-brain patients and those right hemispherectomy patients for whom relevant data are available. Subjects deprived of their right hemisphere should tend toward "hyper-dominance" type symptoms in this case, but the opposite is true: as noted earlier, these patients show all the symptoms of hypo-dominance, including egocentricity, affective lability, and apparent lack of concern about the social consequences of their

behavior. The functional meta-system model accounts for this, and the fact that split-brain subjects do not tend to develop pathological symptoms, by hypothesizing that the right hemisphere normally monitors the environment for significant (e.g., social) stimuli, relates them to personal experience, and signals the left hemisphere appropriately via the (subcortical) limbic system.

Perhaps the most important asset of the proposed model is the fact that a rigorous and comprehensive test of the full range of its predictions can be accomplished with existing technology. The essential cortical-limbic system hyperconnection postulate could be evaluated by observing galvanic skin response (GSR) on the left side in the hyper-dominant group. Augmentation of cortical averaged evoked potentials (AEP) to increasing stimulus intensity would be predicted in the hypo-dominant group and reduction in the other, thus verifying the predicted cognitive mode. Differences in the contingent negative variation (CNV) between obsessives, anxiety neurotics, hysterics, and psychopaths were noted earlier and are congruent with the tenets of the model.

An ideal test of the theory would include replication of the cognitive and personality results of the present study, peripheral physiological observations of indices of limbic system function (bilateral GSR), perceptual reactance (augmenting/reducing), and information processing efficiency (CNV). This could be done with cell sizes large enough to permit meaningful comparisons of diagnostic entities to be made within and between groups. Such a study might result in complete operational definitions of

psychopathological phenomena with important implications for the practice of psychotherapy. Such a fully validated model would permit an integrated approach to diagnosis and treatment planning. An analysis of the ordering of events in a pathological psychological process might allow specification of the relationships between significant experiences (recorded in the right hemisphere system), the conditions and manner in which these (and associated generalized expectations) are elicited by stimuli, and the way in which those are interpreted and/or dealt with by the left hemisphere system. This information would allow the goals of the treatment process to be operationalized and indicate intervention points and methods. Such a plan might specify, for example, that a specific corrective emotional experience or metaphorical association of specified generalized expectations to an identified stimulus, followed by a well-defined cognitive behavior modification and a particular social skill enhancement would be the most efficient intervention package. Finally, biofeedback techniques might find new significance in both the processes of diagnosis and treatment.

APPENDIX A
HYPO- AND HYPER-DOMINANCE SPECTRUM DISORDERS
BY DSM III DIAGNOSTIC CLASSIFICATION

Hyper-dominance Spectrum
Disorders

295.30 Schizophrenia, paranoid
type
300.40 Dysthymic disorder
300.21 Agoraphobia with panic
attacks
300.22 Agoraphobia without
panic attacks
300.23 Social phobia
300.49 Simple phobia
300.01 Panic disorder
300.30 Obsessive-compulsive
disorder
300.02 Generalized anxiety
disorder
300.00 Atypical anxiety
disorder
301.00 Paranoid personality
disorder
301.40 Compulsive personality
disorder

Hypo-dominance Spectrum
Disorders

300.81 Somatization disorder
300.11 Conversion disorder
307.80 Psychogenic pain disorder
300.70 Hypochondriasis
300.71 Atypical somatoform
disorder
300.12 Psychogenic amnesia
300.13 Psychogenic fugure
300.14 Multiple personality
300.60 Depersonalization
disorder
300.15 Atypical dissociative
disorder
312.31 Pathological gambling
312.32 Kleptomania
312.33 Pyromania
312.34 Intermittent explosive
disorder
312.35 Isolated explosive
disorder
312.39 Atypical impulse control
disorder
301.50 Histrionic personality
disorder
301.70 Antisocial personality
disorder
301.60 Dependent personality
disorder
301.81 Narcissistic personality
disorder

APPENDIX B
INFORMED CONSENT STATEMENT

Project Title: Functional Brain Systems and Personality Dynamics

You are being asked to participate in a research project which was designed to find out whether certain patterns of perceiving and processing information are related to specific emotional or nervous problems. You were selected because the types of problems you have reported are similar to the ones being investigated. If successful, the study could lead to more effective ways of helping people with those problems.

Participation in this research project will take about 15 minutes of your time. No monetary compensation will be awarded. No identifying information will be recorded so it will be impossible to report your results to anyone and you will not be recontacted. There are no risks or discomforts involved. You will be given a true-false questionnaire by your therapist or case manager; all the researcher will ask you to do is to identify different types of visual patterns and answer a series of nonpersonal questions. You may withdraw your consent and discontinue at any time without prejudice. If you have further questions, you may contact David Lindquist at Mental Health Services, Inc., 374-5690.

APPENDIX C
REVISED SCORING CRITERIA FOR THE STREET (1931) GESTALT COMPLETION TEST.

Credit any response that indicates that the following has been seen:

Item 1: a dog

Item 2: a boat or ship

Item 3: a cat

Item 4: a stove

Item 5: a baby

Item 6: a table

Item 7: a man in uniform with a rifle or a fisherman
with a fishing pole*

Item 8: a horse

Item 9: a rabbit

Item 10: a locomotive

Item 11: a boy on a tricycle

Item 12: a man's face

Item 13: a man kneeling*

*Altered from original in Street (1931)

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BIOGRAPHICAL SKETCH

David Lindquist was born on November 22, 1944, at Mitchell Air Force Base on Long Island, New York. He grew up in a half dozen cities around the country during the forties and fifties and attended as many educational institutions during that period.


During the sixties he dropped out of high school, served in the Air Force, was married and eventually divorced, obtained a high school equivalent certificate, and worked at a variety of jobs. He took courses at community colleges on a part-time basis beginning in 1968, and earned an A.A. degree in 1973.

He came to the University of Florida in 1974, majored in psychology, and received a B.A. degree with high honors in 1976. He worked in several inpatient and outpatient settings while continuing his graduate study toward the doctoral degree in counseling psychology and has developed a specialization in forensic psychology.

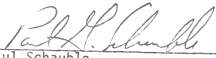
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Professor of Psychology

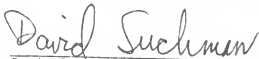
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